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# PERITENDINITIS CALCAREA

## A COMMON DISEASE OF MIDDLE LIFE: ITS DIAGNOSIS, PATHOLOGY AND TREATMENT*

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ROENTGEN examination of the shoulder joint not infrequently reveals the presence of deposits of lime salts in the soft tissues between the acromion and the head of the humerus. These shadows were first described by Painter, an American, in 1907, who regarded them as having arisen in a thickened bursa. Subsequent investigators (Bergmann and Stieda, and others) have shown that the shadows are caused by lime deposits in the soft tissues. According to some authors the calcifications are the results of bursitis (Codman, Brickner, and others), hence the name "bursitis deltoidea" or "bursitis calcarea"; others look upon them as signs of periarthritis (Painter, Codman, Haenisch, Pétrignani, Dickson and Crosby, and others). Several authors (Meyer, and others) have identified the picture with the condition described by Duplay in 1870, "périarthrite scapulo-humérale," also called "Duplay's disease." Still other terms are found in the literature, such as "deposition of calcium salts in the tendon of the supraspinatus muscle" (Harbin, Elmslie).

A few cases have been recorded where similar shadows have been observed close to joints other than the shoulder. Thus Schmitt published a case of bursitis calcarea near the lateral epicondyle of the humerus and Henrichsen a case of calcifications in the same locality. In 1923 Stegemann demonstrated calcification of the bursae in the neighborhood of the hip joint, at the seat of the deep trochanteric bursa. Grashey published a case of calcification of the tendon of the gluteus medius. In 1926 Ayzac reported a few cases of calcifications close to the hip and elbow joints which he considered located in the periarticular bursae.

In 1929, in a large amount of material from the Maria Hospital in Stockholm, I was able to demonstrate that the calcium dense shadows with which we are here concerned are found not only near the shoulder joint but not infrequently also in other parts of the body. The local symptoms of which the patients complain are identical, wherever the localization. In my opinion we deal with a disease *sui generis* for which at that time I proposed the name "peritendinitis calcarea."

### PRESENT MATERIAL

Further studies of a clinical material now amounting to 320 cases, and a joint pathologic-anatomic study with Dr. F. Wahlgren of specimens removed from dif-

* From the Roentgen Departments of the Maria Hospital (Chief, Dr. Å. Åkerlund) and the St. Erik Hospital (Chief, Dr. C. Sandström), Stockholm, Sweden. Read at the Fifth International Congress of Radiology, Chicago, Ill., Sept. 13–17, 1937.

ferent localities of the body have confirmed the assumption that we are dealing with a definite disease entity with a typical clinical picture. The characteristic feature of the condition is the calcification in the soft tissues, found on roentgen examination and located in tendons and tendinous tissue, ligaments and articular capsules, and in their surrounding connective tissue.

There is another term which would well characterize the disease, viz., lime gout, since the clinical picture and the course of our disease very much resembles that of uric acid gout. This term, however, has long been used to imply another clinical picture in which lime is found deposited within and closely underneath the skin in different parts of the body, often in the fingers. This condition shows very little resemblance to uric acid gout, so the name "lime gout" is not a particularly appropriate one. It would be better to use the name "lime gout" as a synonym for peritendinitis to cover the condition here discussed and to follow Steinitz and call these rare subcutaneous and cutaneous lime deposits "calcinosis circumscripta" and "universalis" respectively.

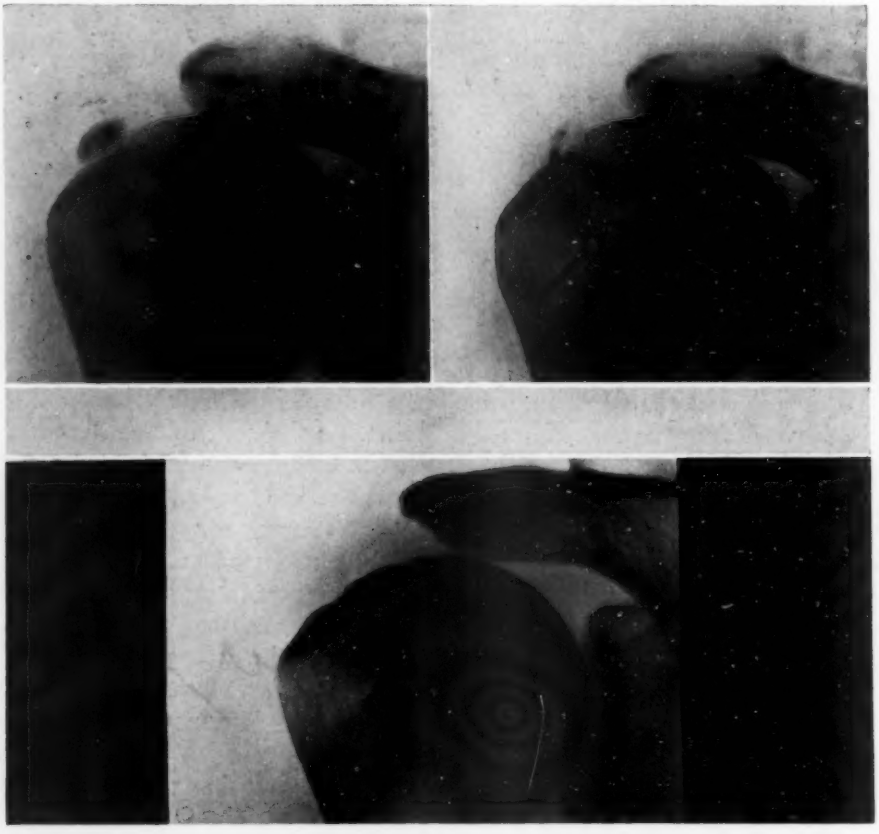


Fig. 1. A calcification near the greater tuberosity. Roentgen treatment. After four months the shadow has disappeared.

*Nomenclature.* The name, which I proposed, was based upon the analysis of roentgenograms and there exists no doubt that in the majority of instances the location of the shadows is the peritendinous tissue. Though later pathologic examinations have revealed that in single instances the proposed name does not fully correspond with the anatomic location, the exceptional discrepancy does not seem to warrant a change of name.

*Clinical Picture.* The clinical picture and

course of the peritendinitis may be divided into the acute, chronic and latent form.

The *acute form* presents the following symptoms:

1. Pain, often marked, not seldom intense.

2. Local edematous swelling, absent in mild cases.

3. Tenderness on pressure often so intense as to render the wearing of clothes unbearable.

4. Restricted motility. In the most severe cases, active as well as passive motility is completely inhibited. In the less severe cases it is generally the active movements that are limited most while passive movements can be carried out to a greater extent.

5. Fever. Out of 80 cases, whose temperature was checked, but 10—of very mild nature—had a normal temperature. Others had a subfebrile temperature or fever. The highest temperature recorded was 40° C.

6. Increased sedimentation velocity of the red cells. Out of 75 acute cases the reaction was normal in but 5 cases. The highest figure recorded was 96 mm. in one hour versus a normal value of 4 to 8 mm. Fifty-eight cases showed values between 20–40 mm. in one hour.

7. Calcifications roentgenographically demonstrable in the soft tissues parts of the affected region.

8. Disappearance or diminution of the calcium deposits with great regularity after roentgen treatment, sometimes spontaneously (Figs. 1 and 2).

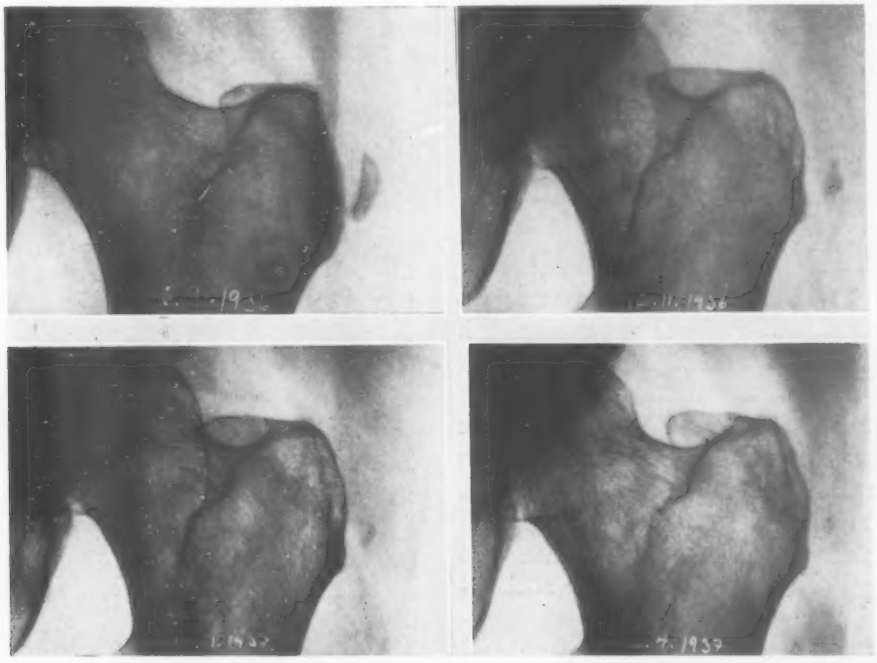


Fig. 2. Calcification near the greater trochanter. Roentgen treatment. After seven months a trace remains.

The *chronic form* presents more insignificant symptoms, such as pain, especially on movement, and local tenderness. For making a definite diagnosis the finding of calcifications in the roentgenogram is necessary. Not infrequently the chronic cases show sudden flare-ups.

In *latent* cases lime deposits are incidentally found on roentgen examination, typical in regard to form and location, but at the moment producing no symptoms. In 20 cases of this nature, the patients were

followed for as long as five years; 12 of these after a longer or shorter time showed more or less sudden symptoms of the disease, sometimes after trauma.

*Differential Diagnosis.* Regarding the differential diagnosis, the acute cases may be mistaken for acute septic conditions, such as arthritis, osteitis and phlegmons. A common mistake is that the condition is regarded as uric acid gout, particularly if localized to fingers and toes. It is striking to note how the symptomatic pictures of peritendinitis and uric acid gout resemble one another, particularly in the acute cases. One observes the same rapid onset, the same intensive pain and tenderness and the same edematous swelling in the two conditions; both may have fever and increased sedimentation rate. I think, however, there is a difference in the discoloration of the swelling which in peritendinitis is not of the same livid hue as in uric acid gout but of a paler color. In every case of acute gout one should roentgenograph the affected part during the attack, particularly if the symptomatic picture is in any way atypical—as, for example, if there is no definite increase of the uric acid in the blood. Only in very few cases of unquestionable acute peritendinitis have I failed to demonstrate any calcifications, yet there have been no signs of uric acid gout. It may be that in these cases it has been a question of microscopical lime deposits which our present methods of examination have failed to bring to light.

Table I

| | Females | Males |
|---|---|---|
| 20–29 years | 2 | 5 |
| 30–39 years | 11 | 27 |
| 40–49 years | 70 | 57 |
| 50–59 years | 54 | 57 |
| 60–69 years | 18 | 22 |
| 70–79 years | 4 | 1 |
| 80–89 years | 1 | 0 |
| | 160 | 169 |

*Age Incidence.* The occurrence of the disease shows no difference in males and females. The age distribution appears from Table 1. It shows an even spread of the disease from forty to sixty years of age in the middle age.

### Roentgen Diagnosis

In many cases there is no difficulty in visualizing the lime deposits. Often a special roentgen technique is required. The lime deposits may be too thin to appear on a roentgenogram taken in the ordinary manner of a skeletal part where the soft parts are often overexposed. In many cases, therefore, it is necessary to take special roentgenograms on which the structure of soft parts can be studied.

Quite often the calcifications are located close to skeletal parts and thus disappear against the shadow of the bone. In this way even large deposits of lime may be hidden by the head of the humerus or the great trochanter. It is then necessary to take roentgenograms in several different planes and directions. Near the shoulder joint, for instance, calcifications may be

Fig. 3. A thin calcification near the greater tuberosity. An acute case.

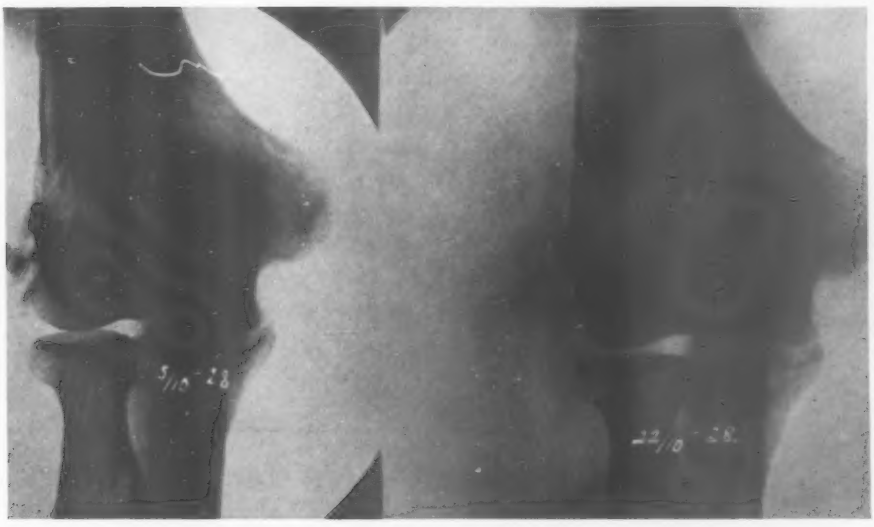


Fig. 4. Nodular calcifications near the external condyle of the humerus. Seventeen days later the nodular portions of calcification have disappeared. A more diffuse deposit extending down to the head of the radius has appeared in the interval. Three weeks later all calcification has disappeared.

found in front of as well as behind the joint, and therefore tangential roentgenograms are taken in different planes, thus "shooting around" the bone. In very acute cases, because of the patient's pain, it is difficult to carry out such a complete examination. It may thus be of advantage to wait until the pain has somewhat subsided. Personally, I have not found stereoscopic roentgenograms to have any particular advantage since the problem is to obtain a view of the lime salts free from the bone.

The shadows seen in acute cases are often thin and of cloudy character and ill-defined from the surroundings (Fig. 3). In cases of longer standing the shadows are often dense, well set off from the surroundings and homogeneous. In other cases, they appear as small granules or drops, partly confluent with large irregular shadows (Fig. 4). The shadows show no structure; sometimes they show an indication of a stratified arrangement; the calcifications obviously are then localized in certain preformed spaces of the soft tissue. Often the shadows are exceedingly small, appearing as conglomerations of tiny points (Fig. 5); in such cases it may be impossible to make a diagnosis from the roentgenogram alone.

In long-standing cases of peritendinitis it exceptionally happens that one finds an

Fig. 5. Punctate periarticular calcifications of the great toe with marked soft tissue swelling.

indication of bony structure, but the general rule is that shadows with bony structure do not represent the calcification of peritendinitis.

At the shoulder joint, calcium deposits are usually found in the neighborhood of the greater tubercle (Fig. 6); often, however, they are in other places, either close to the joint in front of or behind or at a

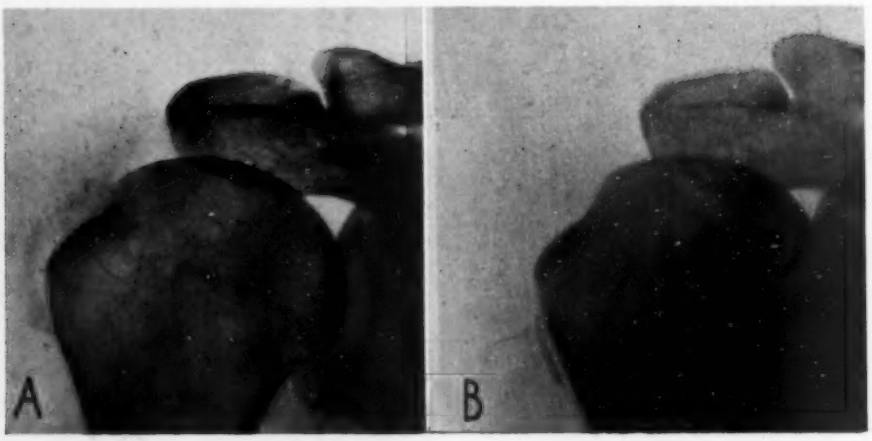



Fig. 6. A thin shadow. Roentgen treatment. After seventeen days a trace remains.

Fig. 7. Calcification near the lesser tuberosity.

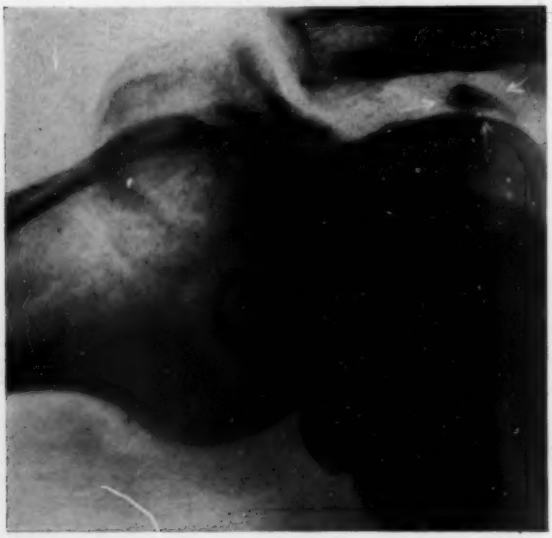


Fig. 8. Calcification near the coracoid process.

greater distance from the joint. A common localization is near the lesser tubercle (Fig. 7). Sometimes they are found near the acromion, within or close to the attachment of the deltoid or else close to the coracoid process (Fig. 8), or at the lower or upper margin of the glenoid cavity (Fig. 9). In other cases, calcifications may be

Fig. 9. Male, aged thirty-one. Calcifications near the tubercles, the upper and lower margin of the glenoid cavity.

found in the humeral attachment of the deltoid or in the soft structures on the inner side of the upper arm (Fig. 10).

In regard to other parts of the arm, I have found calcifications close to the lateral epicondyle of the humerus, the styloid process of the ulna, and in the fingers (Fig. 11).

At the hip joint the calcifications are commonly found close to the greater trochanter, above its apex or close to its outer aspect (Fig. 12), further near the lesser trochanter and close to the acetabulum (Fig. 13).

Fig. 10. (*Right*) Several lime deposits projected against the head of the humerus. A pea-sized shadow below the joint at the point of insertion of the teres major muscle.

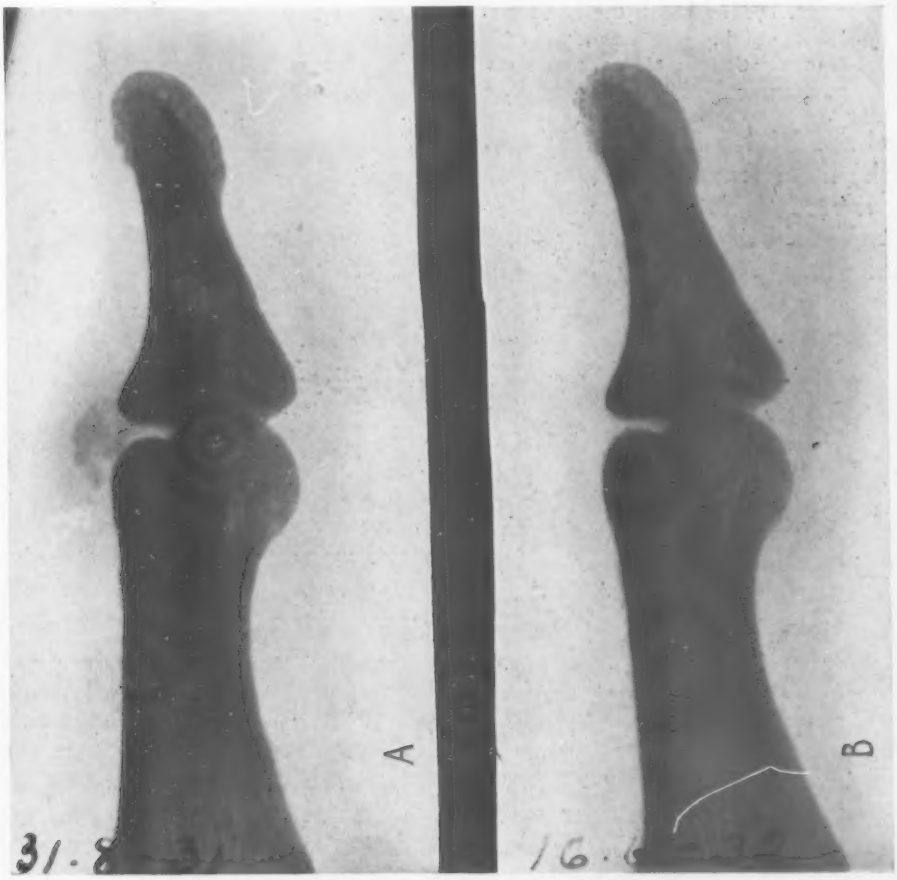



Fig. 11. Periarticular calcification of thumb with marked soft tissue swelling. Roentgen treatment. Ten months later the calcification has disappeared.

Fig. 12. 1929: Pain in the hip for three months. Roentgenogram showed a little calcification adjacent to the acetabular margin. No treatment. 1937: Pain in the hip for two months. Roentgenogram shows that the little shadow has disappeared spontaneously. New calcifications have occurred near the greater trochanter.

At the knee I have found calcifications close to the inner femoral condyle and at the outer aspect of the joint near the fibular head and in the region of the foot in the heel and the toes, particularly in the great toe.

Among the 329 cases observed, the location of the disease was as follows:

| | |
|---|---|
| Neighborhood of the shoulder joint | 259 cases |
| Neighborhood of the elbow joint | 6 cases |
| Neighborhood of the wrist | 2 cases |
| Fingers | 6 cases |
| Neighborhood of the hip joint | 48 cases |
| Neighborhood of the knee joint | 5 cases |
| Toes | 3 cases |

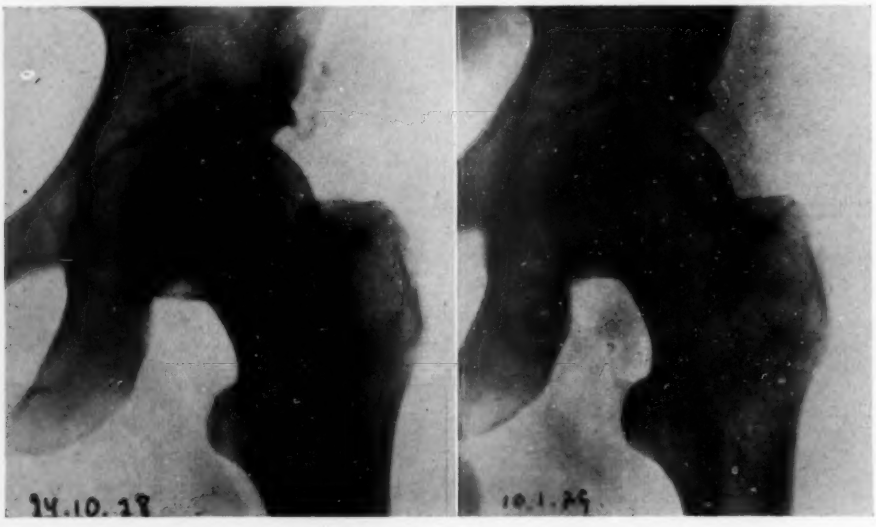


Fig. 13. A calcification adjacent to the acetabular margin. Roentgen treatment. After ten weeks the shadow has almost disappeared.

In 142 cases the condition was localized to the neighborhood of two joints (both shoulder joints or shoulder and hip). In 5 cases the disease was found in 3 or more different parts of the body, the different foci appearing sometimes simultaneously, more often separated by intervals of years.

*Differential Roentgen Diagnosis.* There would seem to be little need of differential diagnosis in regard to the lime deposits, once they have become visualized on the film. The differentiation of these shadows from calcifications in lymph nodes, blood vessels and from remains after metal salt injections and other form of foreign bodies (encapsulated parasites) requires but brief mention. The same is true in regard to the calcifications of enchondroma in joints and bursae and other tumors. More important

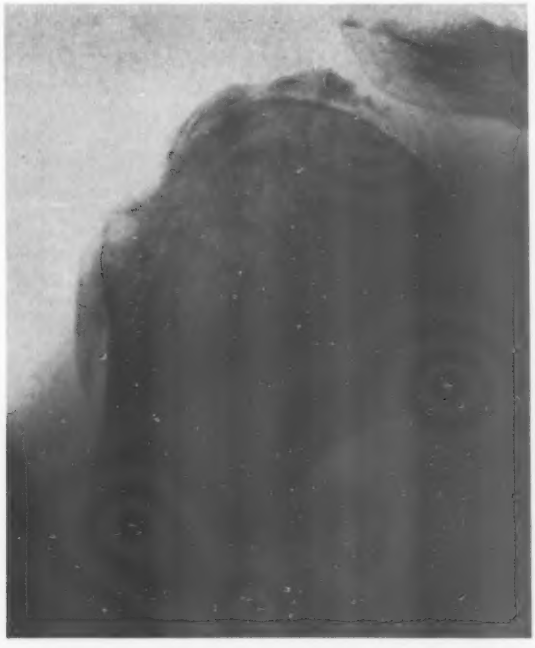


Fig. 14. Male, aged forty-two. Two years earlier, trauma. Roentgenogram shows extensive shadows around head of the humerus with bone structure of traumatic origin (myositis ossificans), not peritendinitis calcarea.

is the differential diagnosis between post-traumatic myositis and tendinitis ossificans and various forms of senile proliferative processes emanating from periosteal joint capsules, tendons and fascial tissues. In the post-traumatic conditions early structureless lime deposits are soon absorbed or replaced by shadows with bone structure

Fig. 15

(Fig. 14). The senile alterations of the tissues in question often represent formation of bone and scrutiny of the films does not fail to reveal the bone structure.

### Pathologic-Anatomic Investigations

According to the early gross examinations by Painter, Bergemann and Stieda, Haenisch, and others, the lime deposits are located in the bursae, a finding confirmed by subsequent investigators (Usland, and others). Contrary to this, Wrede in 1912 showed that the calcifications were located in the tendon of the supraspinatus and not in the bursae. Several subsequent investigations, such as those of Brickner, Carnett and Case, have verified this latter localization. Others (Cooperman, and others) maintain that the calcifications are situated both in the tendon of the supraspinatus and in the walls of the subdeltoid bursa.

Histological examinations are few. The earliest (Bergemann and Stieda, Haenisch) show chronic nonspecific inflammation of the bursae with necrosis and lime deposits. Wrede showed the changes to be present in the tendons of the supraspinatus and infraspinatus, possibly also in the periarticular connective tissue, changes partly of necrobiotic, partly of inflammatory nature. Moschcowitz localizes the disease process to the tendon of supraspinatus and characterizes it as a "tendinitis." He found as characteristic changes necrosis of the tendinous tissue as a result of poor blood supply and a vascular granulation tissue around the degenerated parts of the tendon. Elmslie, in 1932, observed no necrotic changes but an inflammatory process assumed to be secondary to the lime deposits, similar to what is seen in the case of other foreign bodies in the organism.

Since the pathologic-anatomic investigations hitherto published have failed to give consistent results and as these with very few exceptions have only referred to calcifications at the shoulder joint, I have

TABLE II

MACROSCOPIC AND MICROSCOPIC LOCALIZATION OF CALCIFICATIONS

| Case | Sex | Age | Location | Macroscopic Position | Microscopic Position |
|---|---|---|---|---|---|
| I | M | 41 | Right shoulder | Para-articular tissue corresponding to $\frac{3}{4}$ of circumference of articular head | Tendinous tissue, wall of bursa |
| II | F | 44 | Right shoulder | Para-articular tissue, in and around tendons of supra- and infraspinatus | Tendinous tissue, peritendinous connective tissue |
| III | M | 33 | Right shoulder | Tendon of supraspinatus | Tendinous tissue |
| IV | F | 46 | Right shoulder | Tendon of supraspinatus, adjacent peritendinous connective tissue and joint capsule | Tendinous tissue, peritendinous connective tissue, joint capsule |
| V | M | 47 | Right shoulder | Tendon of supraspinatus and peritendinous connective tissue | Tendinous tissue, peritendinous connective tissue |
| VI | M | 40 | Both shoulders | Tendon of supraspinatus | Tendinous tissue, peritendinous tissue |
| VII | M | 62 | Right shoulder | Tendon of supraspinatus, peritendinous connective tissue | Tendinous tissue, peritendinous connective tissue |
| VIII | M | 58 | Right shoulder | Attachment of deltoid and para-articular connective and tendinous tissue | Tendinous tissue, muscular tissue, peritendinous connective tissue |
| IX | M | 79 | Near left hip | Tendon of pyriformis | Tendinous tissue, muscular tissue |
| X | F | 47 | Near right hip | Tendon of gluteus medius | Tendinous tissue |
| XI | F | 42 | Left heel | Tendinous tissue, connective tissue and periosteum | Tendon-like tissue |
| XII | F | 69 | Near left knee | Tendon of gastrocnemius and biceps femoris, joint capsule and periosteum | Tendinous tissue, joint capsule, periosteum |

in collaboration with Dr. F. Wahlgren carried out a pathologic-anatomic examination of 13 cases.

In one case, diagnosed roentgenographically, where the patient died of another disease soon after the examination, I secured the shoulder at autopsy. As seen from the drawing of the post-mortem specimen the lime is scattered as larger or smaller foci in the joint capsule, the tendinous tissue and the peritendinous connective tissue within a large part of the articular region (Fig. 15).

The questions which we have tried to answer are: (1) Where are the calcifications located? (2) What are the microscopical changes? (3) Are the lime deposits of primary or secondary nature?

The calcifications in our material are localized partly to tendons and tendinous capsular and ligamentous tissue of coarse trabecular structure and containing few cell nuclei, partly to undifferentiated cellular connective tissue surrounding joints and tendons (Table II).

Fig. 16. Female, aged forty-six. Roentgenogram shows calcification near the greater tubercle. Macroscopic localization of the calcifications: the supraspinatus tendon and the peritendinous connective tissue between the tendon and joint capsule. Microscopic localization: supraspinatus tendon, peritendinous connective tissue and joint capsule.

Fig. 17. Female, aged sixty-nine. Roentgenogram shows extensive calcifications near the external femoral condyle.

Case IV. A woman, aged forty-six. Roentgen examination showed calcification near the greater tubercle. Macroscopic localization of the calcifications: the supraspinatus tendon, peritendinous connective tissue and joint capsule (Fig. 16).

Case XII. A woman, aged sixty-nine. Pain for six weeks. Roentgen examination showed extensive calcifications near the external femoral condyle (Fig. 17). At operation the calcifications were lying in a sac fixed at the tendon of the gastrocnemius muscle. The calcifications exposed, the thin sac opened (Fig. 18). In Figure 19 the calcifications are removed. The tissue underneath the lime consists of the infiltrated tendon of the gastrocnemius muscle. Small white recesses of the sac remain. Figure 20 shows a diagram of the localization of the lime.

In no case did we find the calcifications in a bursa, in one case possibly in the wall of a bursa. In some, probably older cases, the calcifications were inside small cavities lined with endothelium and located within or outside tendon.

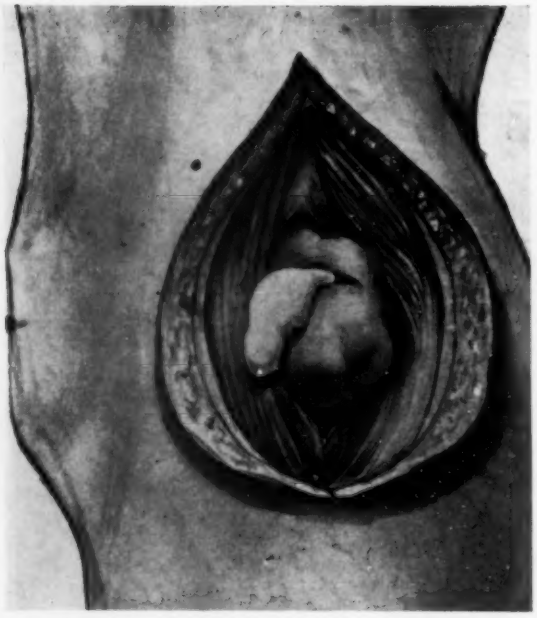


Fig. 18. The same case as in Figure 17. At operation the calcifications were lying in a sac fixed at the tendon of the gastrocnemius muscle. The calcifications exposed, the thin sac opened.

Eight cases of calcifications near the shoulder joint were examined; in 6 cases

Fig. 19. The calcifications removed. The tissue underneath the lime consists of the infiltrated tendon of the gastrocnemius muscle. Small white recesses of the sac remain.

the location was within and close to the tendon of the supraspinatus, in 1 case also close to the infraspinatus tendon and in 1 case in the deltoid attachment.

In 1 case the calcifications were scattered in the para-articular tissue just as in the picture shown.

Regarding the microscopic changes, all our cases showed necrosis and necrobiotic changes in tendons, ligaments and joint capsules with surrounding connective tissue (Fig. 22). The 2 cases with calcifications in muscles surrounding the muscular

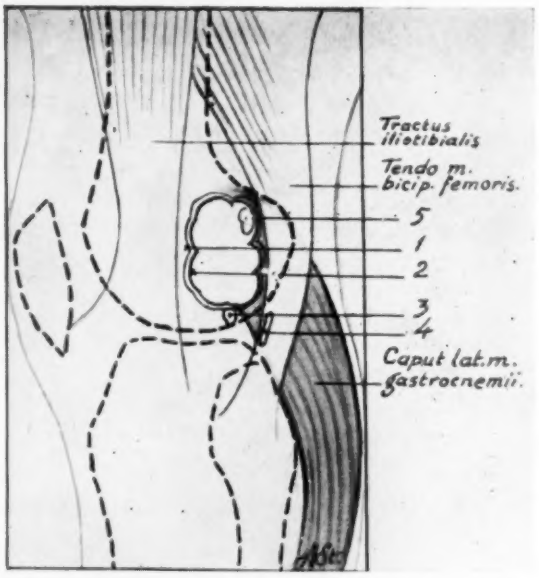



Fig. 20. Diagram of the localization of the lime. *1*, vascularized membrane of the sac; *2*, inner wall of the sac; *3*, lime, fixed at the joint capsule; *4*, lime deposits at the tendon of biceps; *5*, small lime deposit on the periosteum of the lateral condyle.

tissue also showed degenerative changes (Fig. 23).

In 10 cases marked vascular changes were present in the form of hypertrophy of the media with narrowing of the lumen and occlusion of several small arteries (Fig. 24). In some of them we also could find a small thrombus.

There were also signs of regenerative processes in the form of cell proliferation and formation of new vessels. In some cases there were also giant cells of the foreign body type. Eight cases showed in-

flamatory changes with cell infiltrations around vessels and in the granulation tissue. These changes are less pronounced than the necrobiotic alterations (Fig. 25).

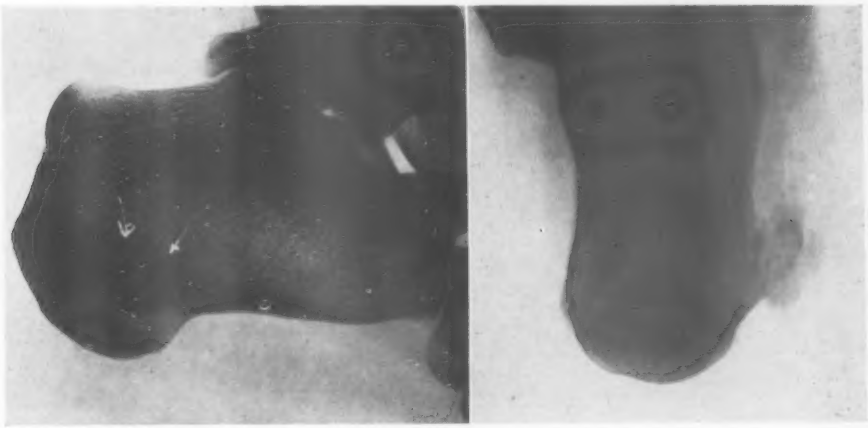


Fig. 21. Calcifications on the lateral side of the calcaneus. Macroscopic localization of the calcifications: connective tissue near the periosteum. Microscopic localization: tendon-like tissue.

In 2 cases there was ossification of the deposited lime.

The histological features thus are made up of alterative, proliferative and exudative changes, all the signs of inflammation.

As to whether the precipitation of the lime represents the very onset of the disease, our investigations give evidence in favor of its occurring on the basis of preexisting degenerative tissue changes; on the basis of the pronounced vascular changes and of the marked alterative changes we assume the disease to consist of local tissue anemia with impairment of vitality. The lime deposits are secondary to these alterations.

*Etiology*. There is little light upon the etiology of the disease. Infection has been considered a cause; others (Bergemann and Stieda, and others) have assumed a chronic

Table III

MICROSCOPIC CHANGES

| Case | Sex | Age | Location | Necrobiotic Changes | Inflammatory Cell Infiltration | Granulation Tissue | Vascular Changes |
|---|---|---|---|---|---|---|---|
| I | M | 41 | Right shoulder | + | + | + | + |
| II | F | 44 | Right shoulder | + | o | + | + |
| III | M | 33 | Right shoulder | + | + | + | + |
| IV | F | 46 | Right shoulder | + | o | + | + |
| V | M | 47 | Right shoulder | + | + (Hemorrhage) | + | + |
| VI | M | 40 | Both shoulders | + | o | o | o |
| VII | M | 62 | Right shoulder | + | + | o | + |
| VIII | M | 58 | Right shoulder | + | + | + | + |
| IX | M | 79 | At left hip joint | + | + | o | + |
| X | F | 47 | At right hip joint | + | o | o | o |
| XI | F | 42 | Left heel | + | + | + | + |
| XII | F | 69 | At left knee joint | + | + (Hemorrhage?) | + | + |

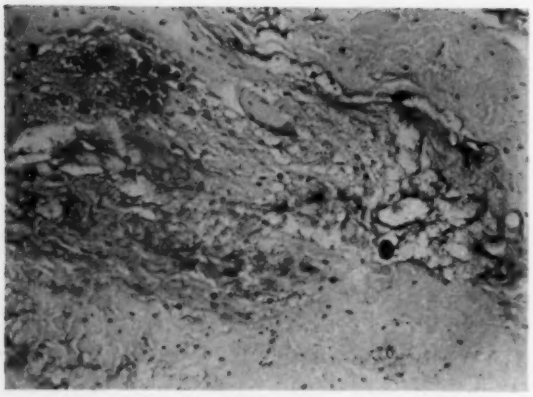


Fig. 22. Extensive regressive alterations in the tendon with calcifications.

trauma to be the cause in connection with the poor vascularization of the tendons (Moschcowitz). Finally some disturbance of the calcium metabolism (Wrede and others) has been proposed. I hope soon to submit the result of an investigation with Dr. F. Wahlgren on the pathogenesis of this condition.

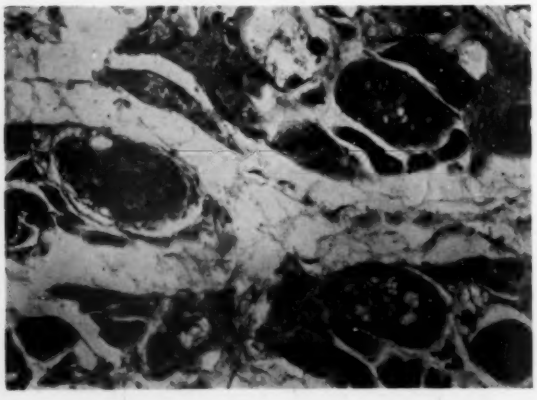


Fig. 23. Degenerative alterations in muscle.

I have been impressed by the similarity which exists between the present condition and true uric acid gout, a similarity which comprises both the acute forms, as referred to above, and the chronic cases with long periods without any symptoms, followed by renewed attacks located in the original site of the disease or in new foci. As long as neither disease is fully interpreted, particularly the mechanism which precipitates the acute attacks, one is at a loss to know just how far the similarity permits the assumption of an identical mechanism of the attacks. On this point it is worth mentioning that we now try to explain the acute attack of uric gout as an allergic phenomenon. We may perhaps consider the clinical picture described above as a condition of similar nature.

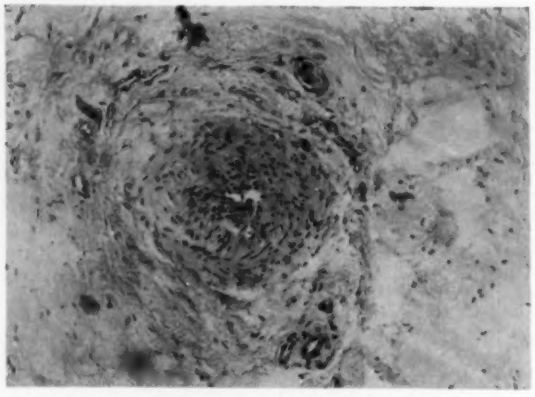


Fig. 24. Small artery with narrowed lumen in a tendon with necrosis and necrobiosis.

TREATMENT

In all my cases the chief treatment has been roentgen irradiation. In 1926 Gösta Renck of the Maria Hospital in Stockholm reported good results from this treatment. In 1929 I reported the results of roentgen treatment of about 100 cases. Good results likewise have been reported from other clinics. The dosage may be characterized

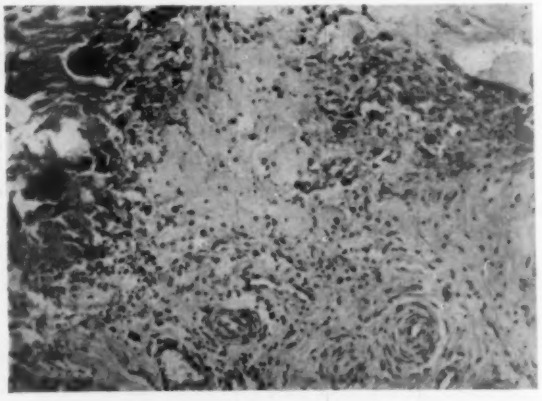


Fig. 25. At the left showing calcifications in the connective tissue with discrete inflammatory infiltration.

as the small doses used to promote alleviation and resorption in acute inflammatory conditions. The dosage used makes possible the occasional continuation of the treatment over a longer period of time in resistant cases.

In detail the technique is as follows:

In *acute* cases: Doses of 75–100 r every other day or every third day, till the acute symptoms have subsided. Thereafter, if slight symptoms persist, treatment is continued as in chronic cases.

In *chronic* cases: Series are given of three treatments of 100 r each. Between the first two or three series there is an interval of three to four weeks; thereafter the intervals are two to three months.

In both acute and chronic cases the fields are varied. The technique employed has been 200 kv., 6 ma., 40 cm. distance, 0.5 mm. Cu and 1 mm. Al filter.

Analgesics have been given temporarily, when needed.

Passive and active movements have been used in accordance with the following principles: in acute cases there is usually little risk of lasting fixation of the joint, particularly the shoulder joint. In chronic cases such risk exists, as is well known, and has to be met with carefully graded gymnastic treatment. Massage is contraindicated as it aggravates the symptoms.

In the acute cases the effect of the treatment is as follows: (1) rapid or sometimes gradual relief of the subjective symptoms, parallel with the disappearance of the objective signs, return to normal of temperature and sedimentation rate; (2) gradual disappearance of the milder symptoms, which often remain after the acute attack; (3) disappearance or diminution of the lime salt deposits.

This last point deserves special mention. By repeated roentgenograms I have followed the process of disappearance in great detail. Sometimes it takes place within two or three weeks, in other cases more slowly. The patient thus may become free from pain and discomfort, while the calcium deposit still remains, usually diminished in size or density. In such cases the treatment is continued until the deposits have completely or almost completely disappeared. In some cases this does not occur, but deposits persist, sometimes with a faint bone structure, due to secondary osteoblastic bone formation.

In more than half of the acute cases the treatment has been finished in two to five weeks. In a quarter of the cases the treatment has continued two to four months. Few cases have been treated for a year. The chronic cases have been treated from two to eight months, in some cases up to a year and a half.

Six patients only have obtained neither subjective nor objective benefit of the treatment. Four have later been operated upon and the deposits been removed. Immediate satisfactory results followed two operations, in the other two slight improvement only was obtained. In these refractory cases renewed roentgen treatment was followed by complete recovery. At operation the calcium deposits were found within sacs lined with endothelium in the tendinous or connective tissue. The conditions of resorption thus no doubt were less favorable than when the deposits are located directly between the fibers of the connective tissue.

The conditions of my work have not made possible the division of the material into two parallel series, one with and the other without roentgen therapy. As mentioned above, the lime deposits may sometimes disappear spontaneously just as the pain may disappear while the deposits remain, and, lastly lime deposits be found without pain, past or present.

To a certain extent control material exists. Numerous cases have, previous to the roentgen treatment, for a longer and shorter time been treated with various kinds of heat therapy, including short wave diathermy. This treatment has not brought relief nor caused the deposits to disappear. My experience, shared by colleagues in Sweden, seems to warrant the statement that roentgen therapy considerably short-

Fig. 26. A calcification near the greater tuberosity. Roentgen treatment. Twenty-seven days later the shadow has disappeared.

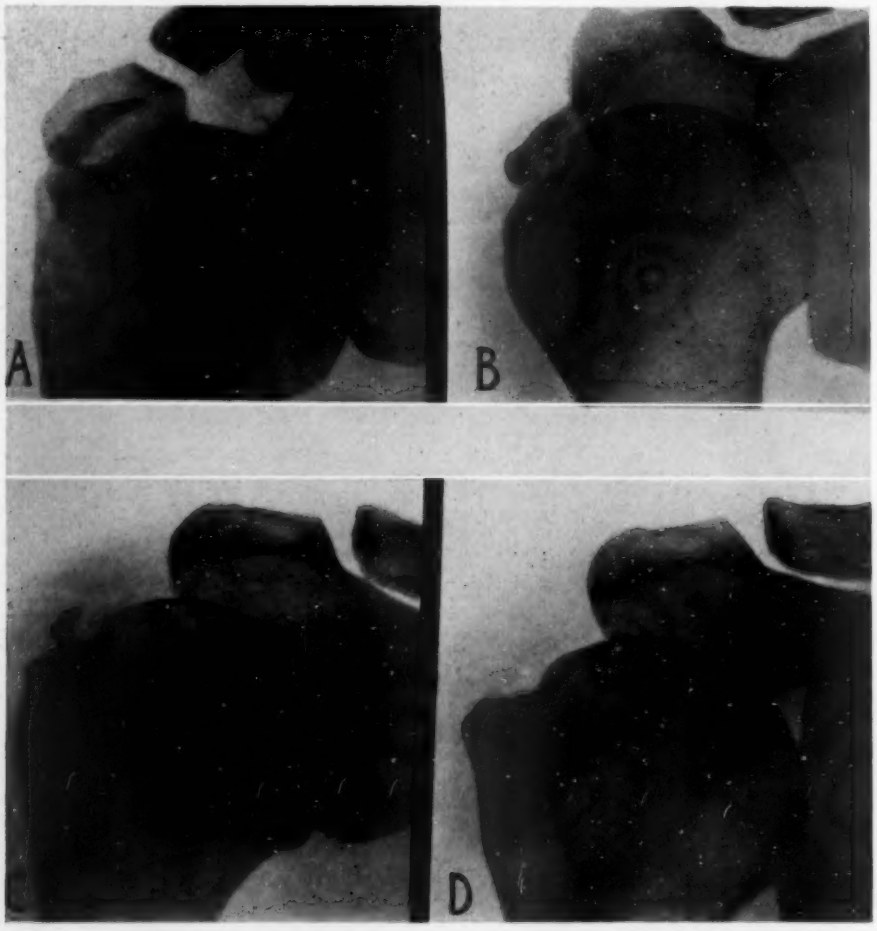



Fig. 27. *A*, calcification near the greater tuberosity. Roentgen treatment. *B*, after three weeks; *C*, after four months; *D*, after nine months.

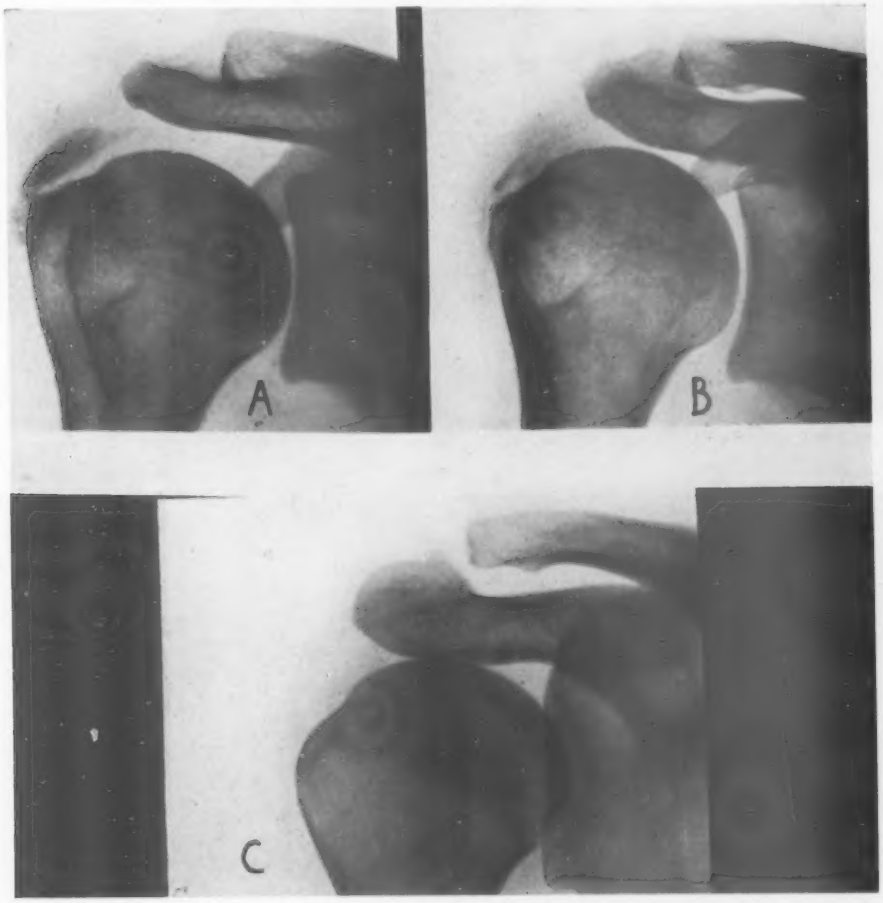



Fig. 28. *A*, calcification near the greater tuberosity. Roentgen treatment. *B*, fourteen days later a trace remains; *C*, after nine months the deposit has disappeared.

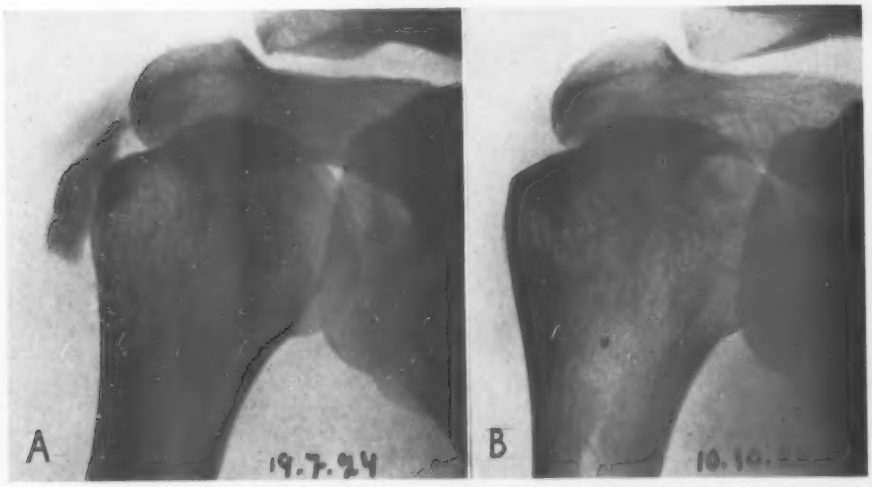



Fig. 29. *A*, calcification near the greater tuberosity. Roentgen treatment. *B*, after three months the shadow has disappeared.

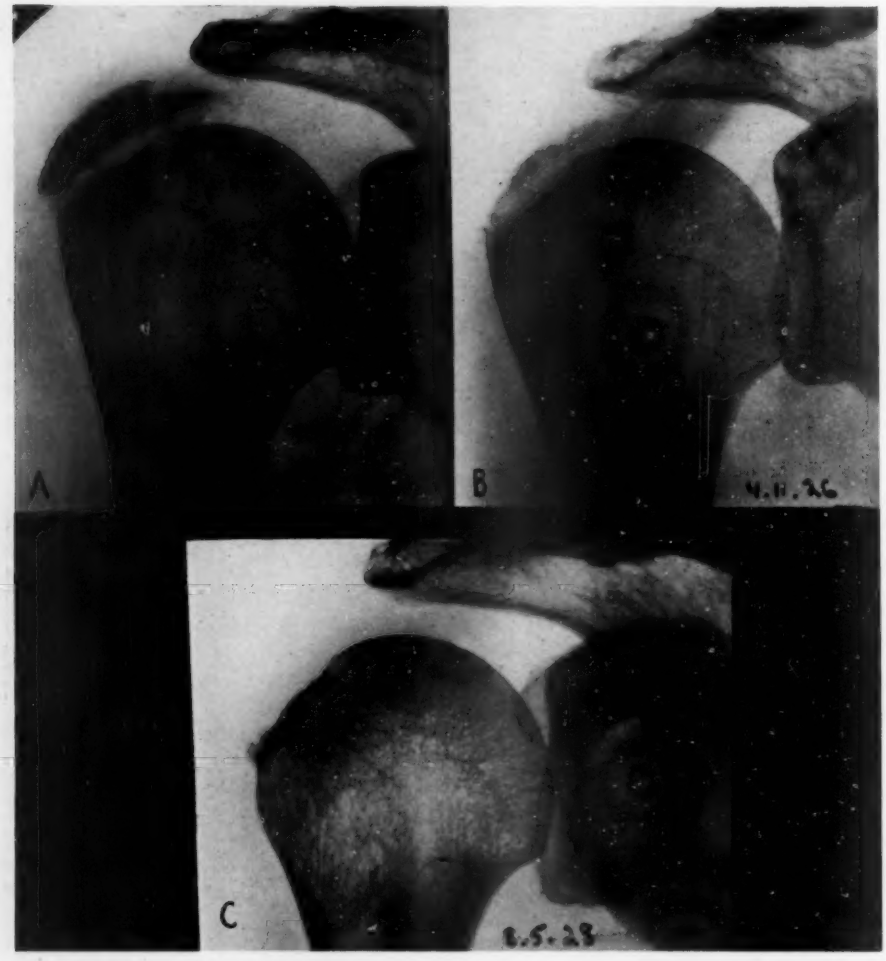



Fig. 30. *A*, massive calcification near the greater tuberosity. Roentgen treatment. *B*, after five months most of the deposit has disappeared; *C*, two years later a trace remains.

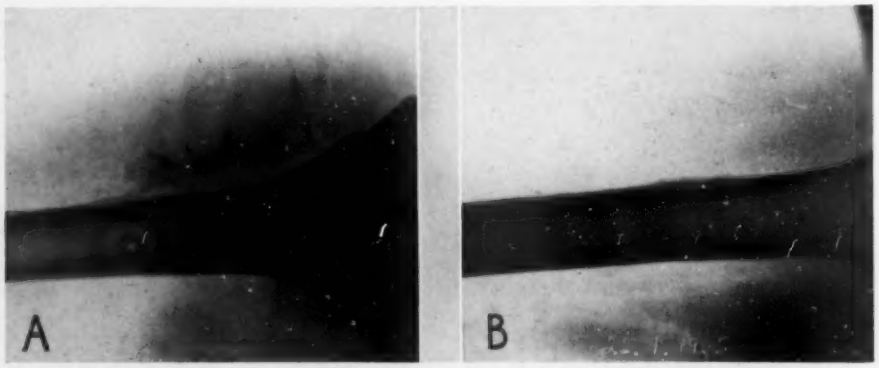



Fig. 31. *A*, calcification near the deltoid ridge on the humerus. Roentgen treatment. *B*, after two months only punctate deposits remain.

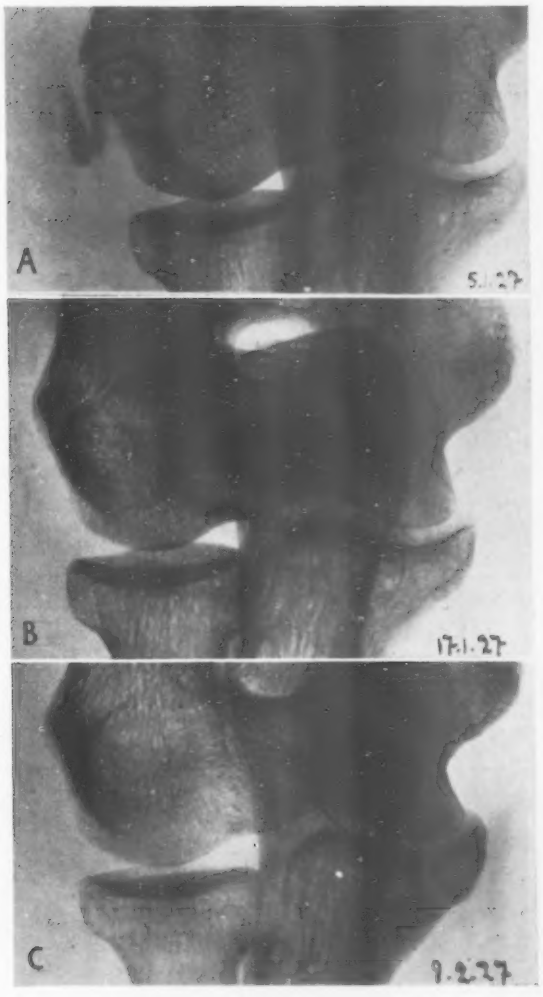



FIG. 32. *A*, thin calcification near the external condyle of humerus. Roentgen treatment. *B*, ten days later only a trace remains; *C*, after twenty days only punctate deposits remain.

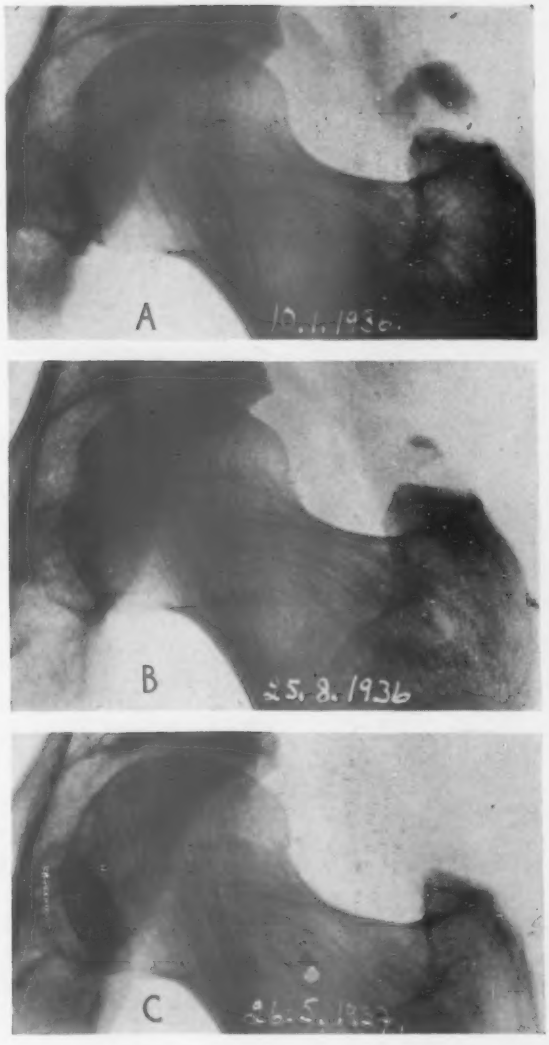



FIG. 34. *A*, calcifications near the greater trochanter. Roentgen treatment. *B*, after seven and a half months most of the deposits have disappeared; *C*, after sixteen months only a trace remains.

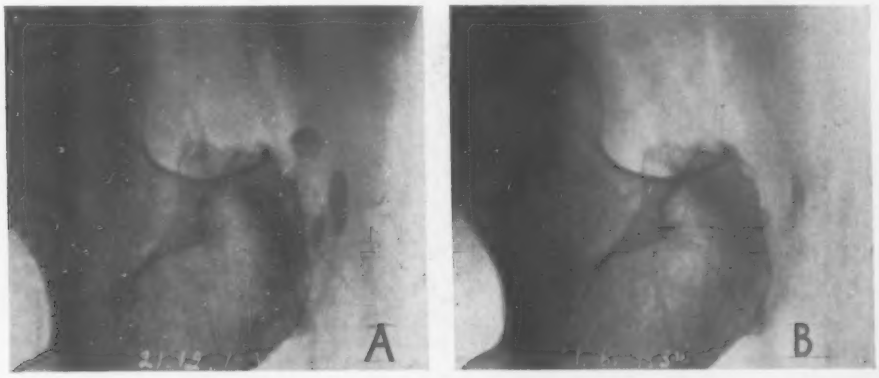
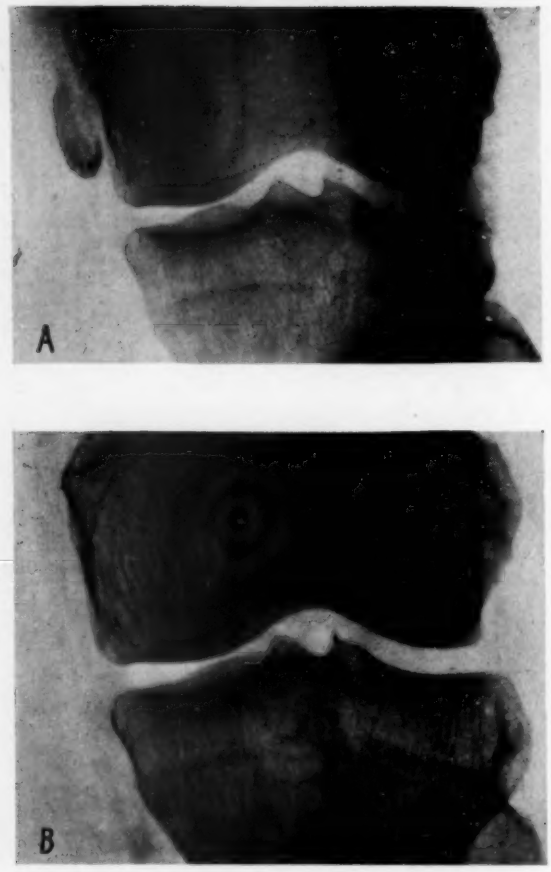



FIG. 33. *A*, calcifications near the greater trochanter. Roentgen treatment. *B*, after seven months the shadows have almost disappeared.




ens the duration of the disease and particularly accelerates the resorption of the lime deposits.

In conclusion, I would like to demonstrate a number of cases where the deposits have disappeared wholly or in part under roentgen treatment. The figures given on the different illustrations indicate the time of disappearance of the lime deposits. Symptoms and signs have as a rule disappeared far earlier (Figs. 26, 27, 28, 29, 30, 31, 32, 33, 34, 35 and 36).

In conclusion, I venture to state that out of the mass of rheumatic and rheumatoid conditions, it is possible for the roentgenologist to separate a disease, which is far from uncommon and which attacks individuals of active age, disabling them for a longer or shorter time. The relation of this disease to calcium metabolism, a field at present in the floodlight of metabolic research remains for future elucidation. Until further experience with this condition in-

Fig. 35. (*Left*) *A*, calcification near the internal femoral condyle. Roentgen treatment. *B*, after five and a half months the shadow has disappeared.

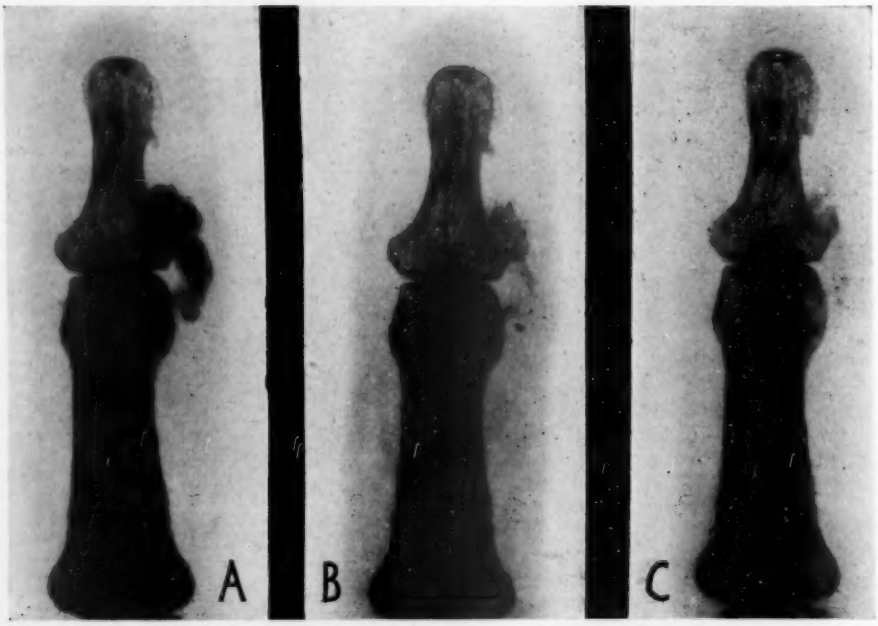



Fig. 36. *A*, calcifications in a finger. Roentgen treatment. *B*, after one month; *C*, after two months the shadows have almost disappeared.

dicates otherwise, roentgen irradiation would appear to be the most satisfactory therapy.

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# NON-PUTRID PULMONARY SUPPURATION*

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## INTRODUCTION

SUPPURATIVE bronchopneumonia is usually a mild disease with a tendency to complete although slow resolution. Roentgenologically, in most cases the infiltrations cannot be differentiated from those of simple bronchopneumonia. In some instances, however, considerable destruction of lung tissue takes place or pleural complications occur which may overshadow the original disease. It is the purpose of this report to review the roentgenologic features particularly of the more severe forms of suppurative bronchopneumonia by means of illustrative cases. The report is intended to supplement that of Jaches[4] made to the Second International Congress of Radiology in Stockholm in 1928.

## DEFINITION

Suppurative bronchopneumonia may be defined as a pneumonitis due to non-putrefactive pyogenic bacteria with the formation of pus in, and sometimes necrosis of, the bronchial walls and pulmonary parenchyma. It is to be differentiated from gangrenous bronchopneumonia which is caused by putrefactive anaerobic organisms, and which in its localized form represents the early stage of gangrenous putrid lung abscess and in its diffuse form is usually the result of a spread from a similar lesion.

## ETIOLOGY

Suppurative bronchopneumonia may be caused by a variety of aerobic organisms including certain strains of pneumococci, streptococci, staphylococci and the Friedländer bacillus. The disease may possibly also be caused by certain anaerobic diphtheroids and streptococci.

## PATHOLOGY

Suppurative bronchopneumonia occurs most often as a complication of purulent sinusitis, whooping cough, measles, influenza and grippe, and after the aspiration of foreign bodies and secretions as in postoperative pneumonia. Suppurative bronchopneumonia is also the usual result of infection distal to any bronchial obstruction (Rabin[8]). During the World War suppurative bronchopneumonia was very common and occurred in a severe form as a complication of measles and influenza. The excellent pathological studies made by MacCallum[6] and others during this period may be taken as a guide. Callender and Coupal,[1] for example, described the method of spread of the infection through the lungs as follows:

> Bronchopneumonia, that is, pneumonic consolidation spreading out from the bronchial tree, was frequent, though rarely the only process present. This type of distribution resulted from extension of the inflammation from the bronchial lumen out into the parenchyma, largely by direct continuity. In some cases the inflammation spread to the walls of the neighboring bronchi, enveloped them and, extending still further, involved the surrounding parenchyma before it penetrated the bronchial wall. A similar gross picture was produced by extension outwards from a lymphangitis or phlegmon of the peribronchial lymphatics resulting from the drainage of pneumonic areas in pulmonary tissue not always supplied with air passages by that bronchus.
>
> The most frequent type of pneumonic consolidation was the lobular which occurred in isolated lobules in lungs, the major portion of which was affected by other types of distribution and took the form of confluent or grouped lobular consolidations varying in extent from small areas to an entire lobe. In a lung where a large proportion of a lobe was involved, it was

* From the Department of Radiology, Service of Dr. Leopold Jaches. Read at the Fifth International Congress of Radiology, Chicago, Ill., Sept. 13–17, 1937.

distinguished from lobar pneumonia by the lack of uniform hepatization, by variations in the character of the consolidation in different and often adjacent lobules, by its apparent extension by continuity at the periphery, and by its tendency to destroy pulmonary tissue. This resulted in necrosis and the formation of abscesses and gangrene.* This type of distribution was the one usually present in lungs showing interstitial lymphangitis or phlegmon, caused by hemolytic streptococci.

Abscesses when formed are usually multiple. This is in contrast to gangrenous lung abscess which is usually single and is confined to a definite bronchopulmonary segment. The condition in suppurative bronchopneumonia might be anticipated from the fact that it is a diffuse disease and that necrosis of phlegmonous areas in the lungs gives rise to multiple suppurative foci which only in certain cases achieve a large enough size to be classed as abscesses and to be identified as such roentgenologically.

Since purulent bronchitis with destruction of the elastic tissue of the bronchioles is a constant feature, bronchial dilatation occurs regularly but it is not always permanent. The dilatation appears rapidly since there may be a paresis of the bronchial muscles; it may be gone in a few months (Schapiro and Jaches[9]). Permanent dilatation with an interstitial fibrosis results in bronchiectasis. Dunham[2] described the process as follows:

> This destruction of the bronchial wall at times extends to and includes the muscular coat, leading to such a marked weakness of the structures that they give way under the sudden pressures to which they are exposed. Clefts in the walls may result leading to acute bronchiectases. The productive inflammation which follows may restore again the normal lumen or may simply lead to a thickening of the dilated bronchial wall and a persistent chronic bronchiectasis. In other cases, when the destruction of tissues has been less deep, the productive processes may predominate and a narrowing of the bronchial lumen be the ultimate result.†

When secretions, often tenacious in character, block this narrowed bronchus or bronchiole, the corresponding portion of the lung may become atelectatic.

It is possible, as Kerley and Chandler[5] have indicated, that in some cases bronchiectasis occurs congenitally and that suppurative bronchopneumonia occurs as a complication. It would appear more likely, however, that generally, bronchiectasis occurs as the result of suppurative bronchopneumonia. Aschner's concept of four types of suppurative disease of the lung was discussed by Jaches previously. Neuhof and his coworkers[7] are publishing their study of the surgical material at the Mount Sinai Hospital. For their concept of pathogenesis and surgical pathology, the reader is referred to their reports.

The streptococcus infections of the lung are often associated with the occurrence of a large pleural effusion. The pleural involvement is apt to come on at the height of the pneumonia in contrast to its occurrence in pneumococcus pneumonia in which it comes on when the pneumonia has practically subsided. Most striking is the rapid organization of the layer of fibrin which generally covers the pleura. This results in the formation of thick red vascular granulation tissues on the pleural surface. Adhesions between contiguous surfaces are quickly rendered permanent and in the later stages, encapsulated pockets of intrapleural origin filled with pus are not infrequently formed and offer difficulties to the surgeon (MacCallum[6]).

Suppurative bronchopneumonia is characterized by a tendency to spontaneous resolution and most cases go on to complete restitution. The average case pursues a mild clinical course. In the sporadic cases, just as in the epidemic cases, different stages of the disease may be present at the same time in different portions of the lungs. There may be, for example, slow resorption of a suppurative focus in one lung, with an abscess forming acutely in the other, perhaps with rupture into the pleura.

The distribution and pathologic course

* It cannot be agreed that gangrene is a feature of suppurative bronchopneumonia. The differentiation has been discussed under "Definition."

† This probably only occurs in the acute stage and is due to swelling of the bronchial wall by exudate.

of suppurative bronchopneumonia in children are similar to that in adults but the endemic form tends to be more severe. Pleurisy commonly occurs over large areas of consolidation. Bronchial glands are apt

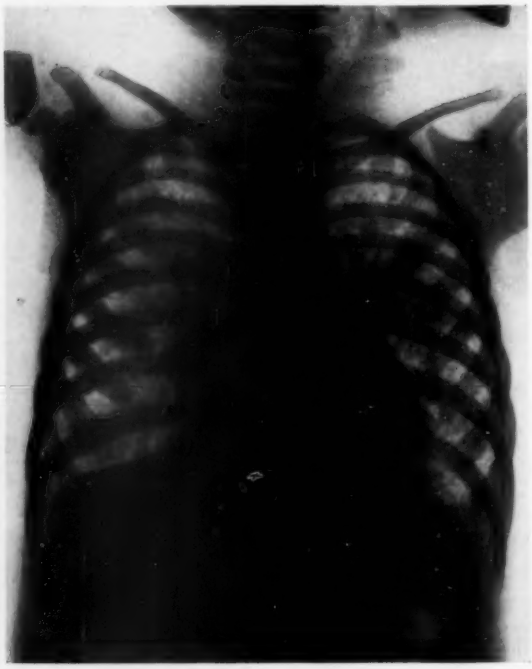


Fig. 1. Case 1. Bilateral suppurative bronchopneumonia with minute suppurative foci scattered throughout the lungs. These are not identified beyond the diffuse bronchopneumonic infiltrations.

to be swollen but not to the size of tuberculous nodes. Holt and Howland[3] call attention to the fact that emphysema is a regular and striking feature in infancy, it being especially marked in protracted cases. It is usually vesicular, involving the greater part of the upper lobes in front and the anterior margins of the lower lobes. Occasionally interstitial emphysema is seen. The matter has been clearly discussed by Snow and Cassasa.[10] They state that the distribution of consolidation or atelectasis in the pneumonia of infants posteriorly and obstructive emphysema anteriorly is because gravity carries most of the secretions posteriorly producing complete block to the bronchi. The bronchi anteriorly are only partly filled and there results a ball-valve obstructive emphysema.

Signs of atelectasis such as elevation of the diaphragm, displacement of the heart and mediastinum to the homolateral side and retraction of the ribs on this side, are found fairly frequently, particularly in children. Since the bronchus leading to the shrunken lobe is found at post mortem to be filled with a thick tenacious secretion, it is to be assumed that this produces the obstructive atelectasis; the signs are often found early in the course of the disease. The atelectasis commonly persists after the bronchial lumen has been re-established and is then due to the presence of exudate and granulation tissue in the interstitial tissues of the lung which maintains the lobe in its shrunken state for an indefinite period.

Abscesses of the lung or, what are better termed suppurative foci within phlegmonous areas, were found in 7 per cent of autopsied cases of bronchopneumonia in children by Holt and Howland. They were usually minute and multiple. In only one case was a true large abscess found occupying the greater part of a lobe. Suppurative foci were found most often in regions where the inflammatory process was especially intense. The abscesses were sometimes superficial but more often were in the interior of the lung.

### Roentgen Characteristics

The milder forms of suppurative bronchopneumonia are difficult to differentiate roentgenologically from the non-suppurative forms and from simple lobular pneumonia. Resolution occurs quite promptly. The roentgen features of the more severe and destructive forms of suppurative bronchopneumonia and its complications are illustrated by the following cases:

### Report of Cases

Case 1. *Purulent Bronchopneumonia with Minute Pulmonary Abscesses.*

B. B., 406408, a female, aged two, was admitted to the Hospital on March 29, 1937, with fever and a cough which had persisted for four days. Physical examination of the lungs showed diffuse fine and crackling râles over

both chests. Breath sounds were normal. There was slight dullness over the right upper and right middle lobes. The throat was injected.

The sputum examination revealed a pneumococcus Type XXVIII. Blood count showed white blood cells, 9,600; 69 per cent polymorphonuclear leukocytes.

Roentgen examination of the chest (Fig. 1) revealed a diffuse irregular mottling in the lungs chiefly extending out from the roots.

The temperature of the patient remained elevated. The right ear began to discharge. Diffuse râles appeared over both chests.

Thirteen days after admission the patient died.

Post-mortem examination (No. 10329) revealed a bilateral suppurative pneumonia with minute suppurative foci scattered throughout the lungs. There was a diffuse fibrinous pleuritis.

Case II. *Solitary Abscess with Rapid Resolution.*

C. A., 403720, a female bookkeeper, aged twenty-five, entered the Hospital on January 20, 1937, with a history that three weeks before she had caught cold and had developed a sense of chilliness, dry cough, and a dull pain in the right anterior chest. Her temperature rose to 102° F. The cough became productive of thick, green-yellow sputum. On the ninth day of her illness at home a diagnosis of bronchopneumonia was made and she was sent to the Hospital.

Physical examination on admission showed impaired resonance, somewhat increased breath sounds and fremitus at the right base. There were no râles. Movement of the chest on this side was limited.

One day later, January 21, 1937, there were slight dullness and diminished breath sounds at the right base.

Blood count revealed white blood cells, 11,450, with 84 per cent polymorphonuclear leukocytes.

Roentgenograms made on this day (Fig. 2) showed a small area of pneumonic infiltration in the lower portion of the right upper lobe within which a small area of rarefaction containing a fluid level was seen. There was evidence of a pleural exudate in the adjacent interlobar fissure.

By January 23, 1937, the temperature was down to 99.4° F. The expectoration, however, was unabated. From this time improvement was progressive. By January 29, 1937, a roentgenogram showed an almost complete disappearance of the process.

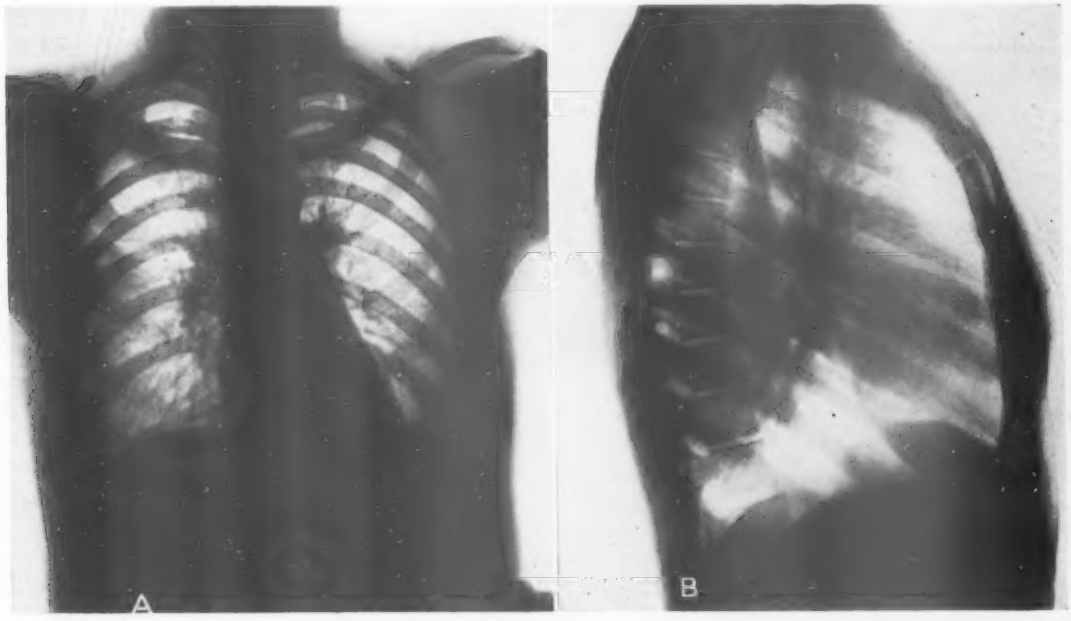


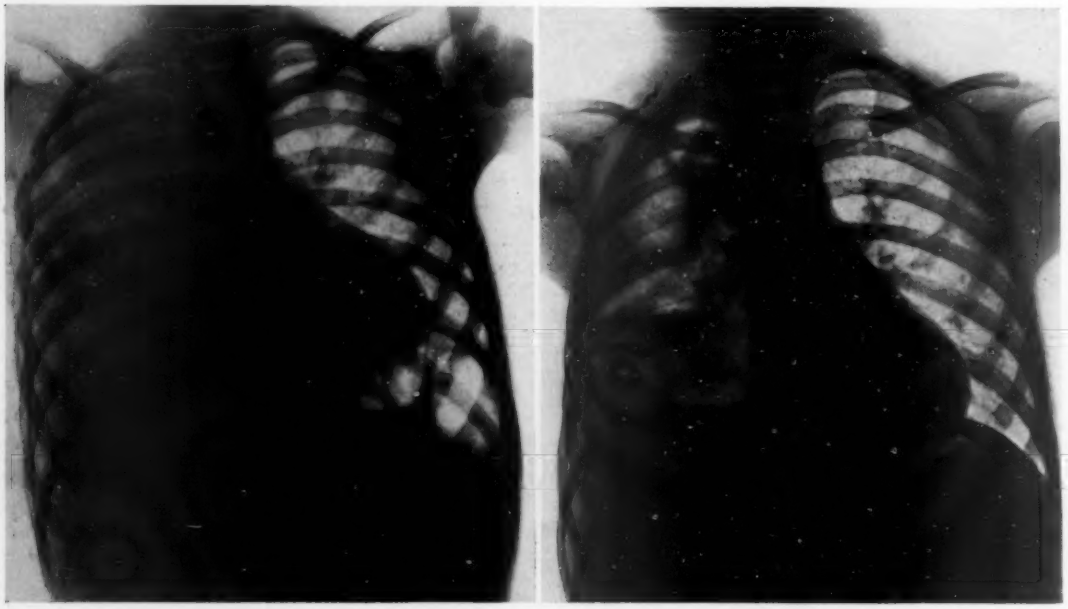

Fig. 2. Case II. Solitary non-putrid abscess in the lower portion of the right upper lobe. Fluid level seen at the level of the seventh rib posteriorly. The lateral view shows evidence of thickening of the adjacent interlobar fissure.

Case III. *Solitary Non-Putrid Abscess: Operative Findings.*

E. K., 390519, a boy, aged eight, was admitted to the Hospital on March 3, 1936. Three and one-half weeks before admission the boy complained of a non-productive cough. His temperature was found to be 103.5° F. and the local physician found redness about the tonsils. The fever persisted for a week. At this time a rash appeared which lasted two days and was diagnosed as measles. The temperature rose again and nine days before admission the roentgen diagnosis of left pneumonia was made. Five days before admission the child again began to cough and expectorated a yellowish, purulent mucus with occasional "tomato juice" streaking. This was odorless. The roentgen examination at this time was said to have shown a fluid level at the site where the pneumonic process had previously been present.

Physical examination of the lungs showed dullness over the left upper lobe anteriorly from apex to fifth rib, extending laterally to the anterior axillary line. There were coarse râles over this region and bronchovesicular breath sounds. Fremitus was normal. The bases moved freely. It was thought by the surgeon and others that the lesion was a lung abscess with perforation probably into the fissure.

Operation revealed the cavity to be entirely intrapulmonary. It was solitary, without recesses and clean except for a small amount of pus on the floor. A bronchial fistula of medium size was found. The abscess lay within the upper lobe directly on the fissure with adhesions to the adjacent lower lobe but without perforation.



*A* *B*

Fig. 3. Case IV. Examinations seven and seventeen days after the onset of illness. The first shows numerous small areas of rarefaction within an otherwise diffusely homogeneous density in the right chest. The second shows definite cavitation. Complete spontaneous resolution three months later.

After operation the patient slowly became fever-free and remained well.

Case IV. *Multiple Abscesses with Spontaneous Resolution in a Child.*

L. A., 404905, a boy, aged four, was admitted to the Hospital on February 21, 1937. Eight days before admission the child was found to have a red throat with a temperature of 104° F. A moderate cough developed four days later, and during the next six days the temperature ranged between 101° and 102° F.

Physical examination of the lungs revealed dullness and flatness over the right lower lobe posteriorly. There was diminished bronchial breathing at the right base. Anteriorly, there was slight dullness over the first three ribs and

bronchial breath sounds with a peculiar whistling quality. The left lung was clear.

Blood examination revealed white blood cells, 8,500; polymorphonuclear leukocytes, 40 per cent. Sputum typing revealed pneumococcus Type III.

Roentgen examination on the day of admission showed a diffuse density occupying the right chest within which were small scattered areas of rarefaction.

The disease passed through a very mild clinical course during the child's eight weeks' stay in the Hospital. The temperature was usually normal, occasionally reaching 101° F. and rarely 102° F. during the first four weeks. During the second four weeks the boy was completely afebrile. Early there was a mild cough with a small amount of non-putrid sputum.

Roentgen examinations were made every week, of which the accompanying reproductions are illustrative:

February 20, 1937 (Fig. 3*A*). An almost homogeneous density is seen occupying the entire right chest with a few small areas of relative transparency.

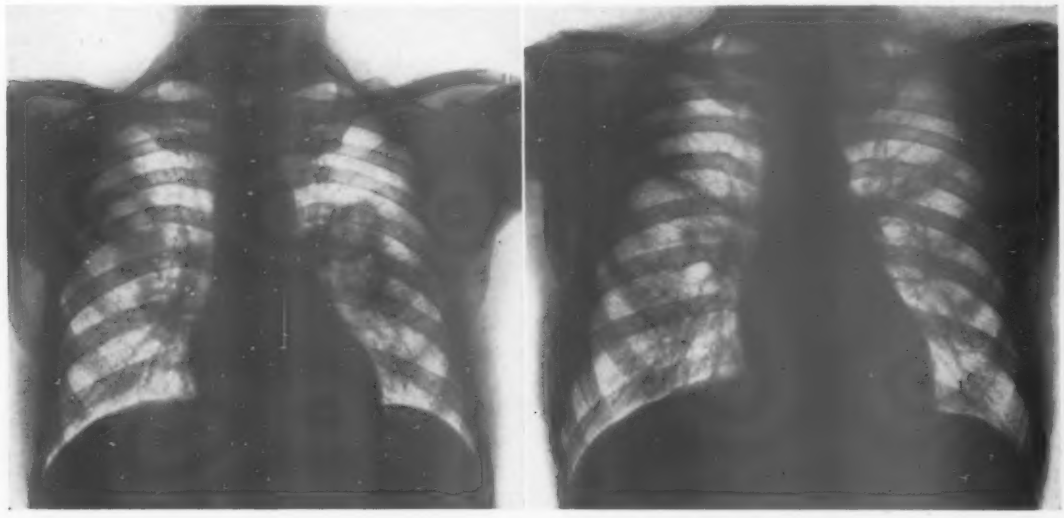
February 24, 1937. The upper half of the density in the right chest includes numerous areas of rarefaction, some of which now show fluid levels.

March 2, 1937 (Fig. 3*B*). The examination again shows evidence of diffuse cavitation in the upper half of the right lung.

March 9, 1937. The areas of rarefaction extend almost to the base of the lung, but the diffuse density has diminished.

March 30, 1937. There is a definite reduction in the density of the shadow in the right lung. The process now is apparently in the upper lobe only. The cavities are not well defined.

June 17, 1937. The lungs are almost entirely clear, except for evidence of a few fibrotic strands in the right upper lobe.



*A* *B*

Fig. 4. Case v. Multiple bilateral non-putrid abscesses. The second illustration shows marked resolution one month later.

Case v. *Multiple Abscess of the Lung in an Adult with Complete Recovery.*

S. L., 376036, a male, aged thirty-seven, was admitted to the Hospital January 25, 1935. Four weeks before admission he complained of general malaise and fever, with the temperature rising to 103° F. Two days later a sore throat appeared which shortly subsided. The patient then began to cough and brought up light brown sputum which was sometimes blood-streaked. At the time of admission the cough was still present with expectoration of non-foul, non-bloody sputum and a temperature which ranged between 99° and 103° F.

Physical examination of the chest revealed slight dullness over the right upper lobe anteriorly. There were post-tussis crackles beneath the outer end of the right clavicle.

The white blood count was 5,250 with 60 per cent polymorphonuclear leukocytes.

Roentgen examination of the chest made on January 26, 1935 (Fig. 4*A*), one day after admission, showed pneumonic infiltrations extending from the roots of both lungs to the periphery. On both sides within these areas of infiltration there were numerous areas of rarefaction, several of which showed fluid levels, indicating the presence of abscesses.

Roentgen and clinical examination showed the presence of a bilateral purulent sinusitis.

The patient ran a low-grade fever with temperatures ranging as high as 102.6° F. In the course of three weeks the temperature slowly fell to normal. Occasional crackles, slight dullness and diminished breath sounds were elicited inconstantly. Small amounts of sputum were expectorated, occasionally blood-tinged.

Bronchoscopy showed no abnormality, except for a small amount of secretion at the mouth of the right main bronchus and at the left upper lobe orifice.

On February 1, 1935, the pneumonic areas were somewhat less extensive but the fluid levels were persistent in the involved area in the right lung and in the upper portion of the pneumonic area in the left lung.

By February 20, 1935 (Fig. 4*B*) there was a marked resolution of the process and the roentgen examination finally showed complete resolution.

A roentgen examination made a year later showed the lungs practically normal. There was evidence of a slight residual fibrosis in the left lung. The patient, clinically, was perfectly well.

Case VI. *Suppurative Bronchopneumonia with Atelectasis.*

A. F., 378960, white male, aged seven weeks, was admitted on April 20, 1935, for a spasmodic cough which had lasted for four weeks. There was frequent vomiting and marked diarrhea for the period immediately before admission.

Physical examination of the lungs showed dullness at the left base posteriorly and in the mid-chest. There were many coarse and subcrepitant râles. There were a few râles in the right chest posteriorly.

White blood count was 17,600 with 58 per cent polymorphonuclear leukocytes.

Roentgen examination (Fig. 5*A*) showed a triangular area of increased density on the left side behind the heart suggesting an atelectatic pneumonic process of the left lower lobe. The heart was displaced somewhat to the left. The left upper lobe appeared relatively emphysematous. Despite the fact that the temperature remained practically normal, the child soon went into collapse, with apparently complete respiratory obstruction, and died on May 1, 1935.

Post-mortem examination revealed a diffuse purulent bronchitis, bronchiolitis and peribronchitis. There was a bronchiectasis of the left lower lobe, and emphysema of the left upper lobe. There was a bronchopneumonia of the right lung. Yellow creamy pus was seen exuding from most parts of the lung, particularly the left lower lobe. The atelectasis described roentgenologically was due to shrinkage of the left lower lobe due to the interstitial pulmonary process. No bronchial plug was found.

Case VII. *Suppurative Bronchopneumonia with Atelectasis.*

M. H., 395065, was a colored girl, aged one year, admitted on June 26, 1936. Two weeks before admission the baby developed a moderately severe unproductive cough. For four days she had been vomiting her feedings, was feverish, restless and perspired profusely. There was a past history of rickets, congenital lues and numerous soft tissue abscesses.

Physical examination of the lungs showed dullness and high-pitched breath sounds in the left lower lobe. There were no râles but coarse ronchi were noted throughout. The tonsils were acutely inflamed. Temperature on admission was 104° F.

The white blood count was 20,800, 88 per cent polymorphonuclear leukocytes.

The temperature fluctuated between 101° and 104° F. for about a week. By July 2, 1936, clinically, there was a complete consolidation of the left lung.

The roentgen examination on June 29, 1936, had shown evidence of a pneumonic process in the left lower lobe with slight pleural exudate. On July 14, 1936 (Fig. 5*B*), small areas of rarefaction were seen scattered throughout the dense left lung with displacement of the heart and trachea to the left. The intercostal spaces appeared somewhat narrowed on this side. There was evidence of a pneumonic process in the right lower lobe.

Despite repeated transfusions the child died on August 6, 1936.

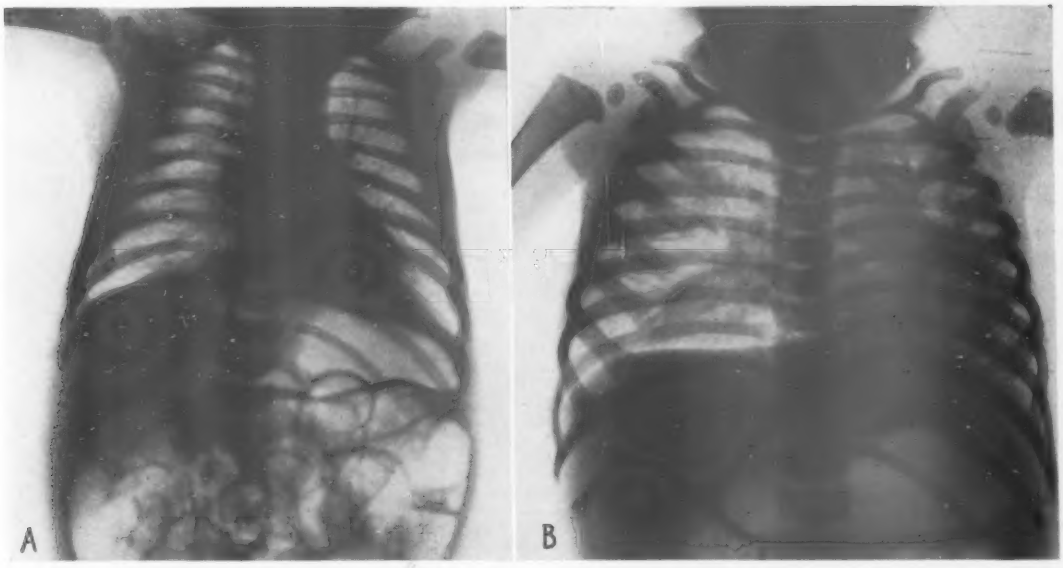



Fig. 5. Cases VI and VII. *A*. Triangular area of increased density on the left side behind the heart representing involvement of a single lobe by an atelectatic suppurative bronchopneumonia. *B*. Similar condition but showing numerous areas of rarefaction representing cylindrical bronchiectases and suppurative foci.

Post-mortem examination (No. 10002) showed a chronic pneumonitis of the left lung, acute and chronic bronchitis with diffuse cylindrical bronchiectases of the left lung, left pleural adhesions, bronchopneumonia right upper and lower lobes and compensatory emphysema of the right lung. Again, the atelectatic features were to be explained by the chronic pneumonitis with shrinkage and fibrosis.

Case VIII. *Suppurative Bronchopneumonia: Bronchial Dilatations Demonstrated by Bronchogram: Complete Recovery.*

L. S., 362057, a male, aged sixteen, was admitted to the Hospital on January 29, 1934. Nineteen days before admission the patient developed a head cold, malaise, headache and temperature ranging to 103° F. He remained in bed for six days with a dry cough which gradually disappeared. He returned to school, not completely well, and had a sudden coughing attack with expectoration of thick yellowish, creamy, purulent material. This attack was repeated several times. The temperature now rose to 104°F., the cough and the expectoration persisting.

Physical examination of the lungs showed dullness, diminished breath sounds and râles at the base of the right axilla and anteriorly below the fourth rib. Similar signs were elicited at the left base posteriorly.

Roentgen examination revealed bronchopneumonia at both bases (Fig. 6*A*). Fluid was suspected clinically at the right base, but aspiration on January 31, 1934, yielded no fluid. The temperature dropped to normal in a week but expectoration persisted. A bronchogram on February 16, 1934 (Fig. 6*B*) showed a general dilatation of the right lower lobe bronchi and globular dilatations, particularly of the anterior descending branches of the right middle lobe and the anterolateral branch of the right lower lobe. On February 27, 1934, there were numerous areas of transparency within the bronchopneumonic areas and a suspicious fluid level at the right base. Bronchoscopy showed mucopurulent secretions in both lower lobe bronchi, particularly the posterolateral branch of the right lower lobe.

The patient gradually improved and finally became symptom-free.

On May 27, 1935, approximately fifteen months later, a bronchogram showed the bronchi to be normal.

Case IX. *Bronchiectasis Following Suppurative Bronchopneumonia.*

A. M., 404558, a female, aged eight, was admitted to the Hospital on February 12, 1937, complaining of fever and cough of one week's duration. One week before this the girl had a running nose, cough and sore throat with low-grade fever. Her cough was now productive

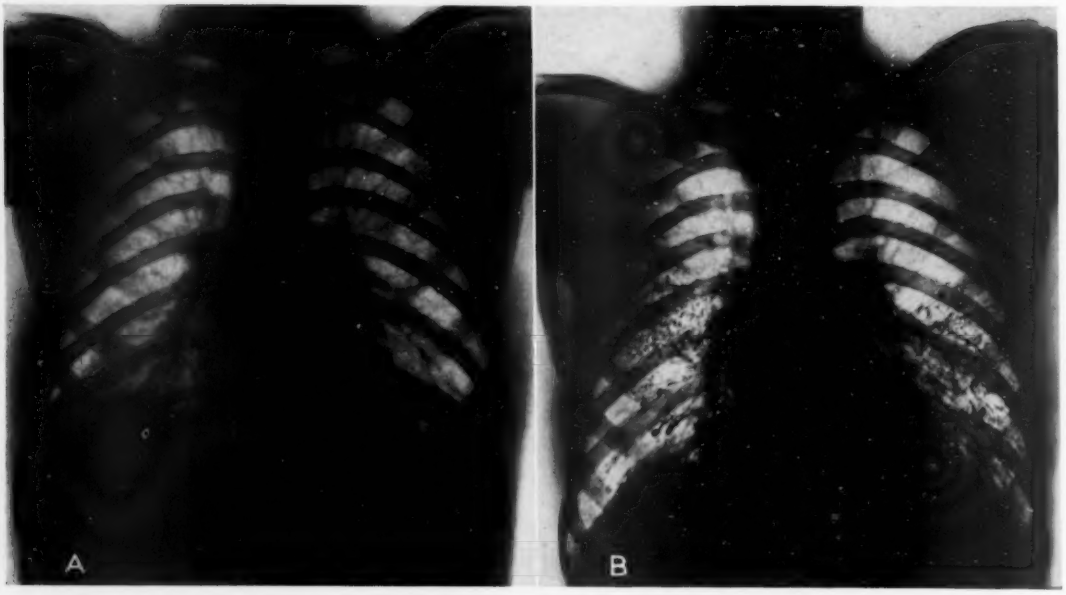



Fig. 6. Case viii. Diffuse irregular infiltrations particularly of the right lower lobe. Bronchogram thirty-one days after the onset of the illness when the temperature was normal shows globular dilatations of the right lower lobe branches. A bronchogram fifteen months later showed normal bronchi.

and her temperature ranged between 101° and 104° F. Two years before she had pneumonia.

Physical examination of the lungs revealed marked dullness over the left lower lobe. There were fine and medium moist râles and the breath sounds were amphoric. Sputum examination revealed pneumococcus Type iv. The temperature persisted for two weeks and then became normal.

Roentgen examination on February 20, seven days after admission, showed an irregular pneumonic process occupying most of the left lower lobe and part of the right lower lobe. By March 11 the pneumonic processes were somewhat diminished but there were areas of rarefaction present which were suggestive of bronchiectasis.

Bronchogram of the left lower lobe on March 25 showed definite dilatation of these branch bronchi. The examination was made eight weeks after the onset of symptoms, when the temperature became normal.

Case x. *Suppurative Bronchopneumonia: Bronchiectasis on the Right: Lung Abscess and Empyema on the Left.*

C. E., 389265, a male, aged forty, was admitted on January 26, 1936. He stated that six weeks before, there was an exaggeration of a cigarette cough which was non-productive. Following a drenching eight days before admission, malaise and a pain in the left posterior chest appeared. He became listless and feverish, with his temperature rising to 104° F. Five days before admission coughing produced a small amount of odorless sputum which was not bloody.

Physical examination of the chest showed flatness, distant bronchial breathing with many râles, and egophony over the left lower chest posteriorly. There were similar signs over the left chest anteriorly and in the right axilla.

Blood count showed 31,400 white blood cells with 92 per cent polymorphonuclear leukocytes. The blood Wassermann was four plus. Sputum typing revealed pneumococcus Type xx.

Roentgen examination on the day of admission (Fig. 7*A*) revealed large paramediastinal shadows on the left suggesting encapsulated fluid collections.

The sputum became profuse and purulent. Aspiration followed by thoracotomy confirmed the presence of a loculated empyema in the mediastinal pleura, connected with a large broken down abscess, with penetration into the mediastinum and the formation of a collection of pus adjacent to the aorta. On February 7 a second thoracotomy revealed a free pleural space empyema which was evacuated. A pneu-

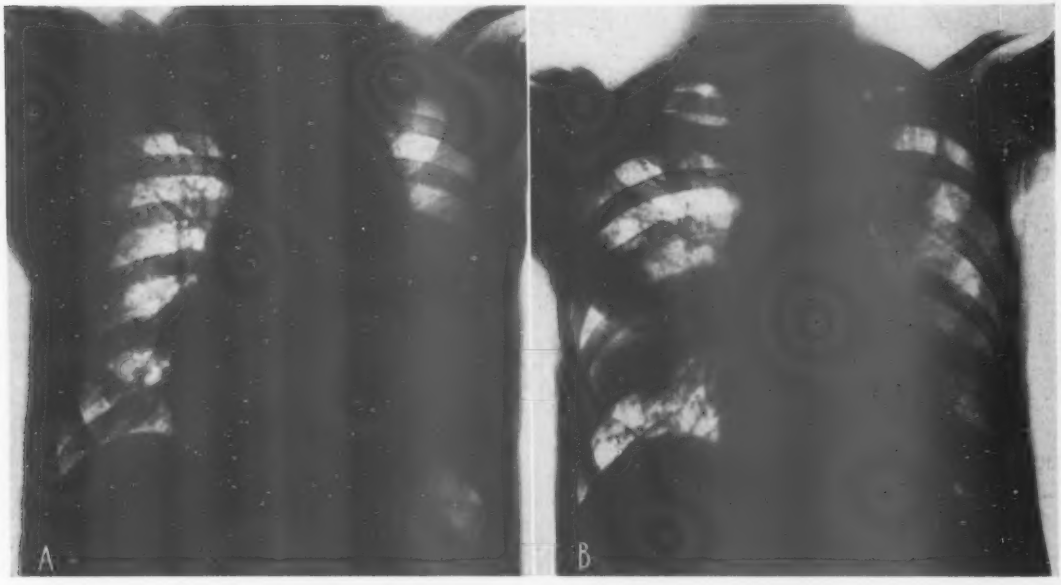



Fig. 7. Case x. *A*. Lobulated homogeneous shadows on the left side, paramediastinally, representing encapsulated fluid collections due to the perforation of a large abscess. A free pleural space empyema was also present. *B*. An examination made one month later showing a right upper lobe abscess which developed after the empyemas were drained.

monic area which had been seen previously in the right lung now began to increase in extent and, on February 10, was quite large (Fig. 7*B*). On March 11 there was the sudden occurrence of severe right chest pain interpreted as a recrudescence of pneumonia on this side and the patient died within twenty-four hours.

Post-mortem examination (No. 9863) confirmed the surgical findings. The left upper lobe abscess was 10×15 cm. with many fistulas. The small bronchioles were dilated due to ectasia. The apical portion of the right lower lobe was honeycombed by numerous saccular bronchiectases.

Case xi. *Large Pyopneumothorax Due to Perforated Lung Abscess.*

C. M., 405773, a female, aged two, was admitted to the Hospital March 14, 1937, with the history that one week before she had a running nose. Three days before admission the child became worse and began to cough. Respirations became more rapid and the child began to grunt.

Physical examination of the lungs revealed a tympanitic note to percussion over the right chest anteriorly and posteriorly. There was dullness over the lower half of the chest to flatness over the base. The breath sounds were suppressed. There was egophony at the right base posteriorly. The temperature was 104° F.

Roentgen examination (Fig. 8) showed the

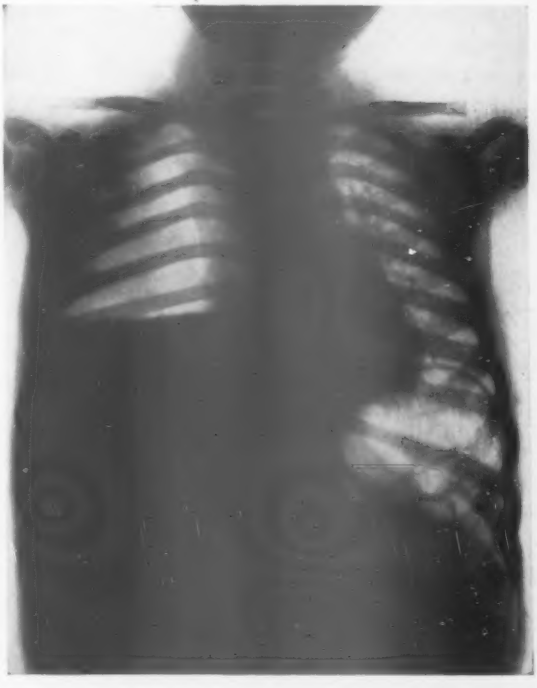


Fig. 8. Case xi. Huge right pyopneumothorax due to perforated non-putrid lung abscess.

presence of fluid and air completely occupying the right pleural cavity, with widening of the intercostal spaces and displacement of the mediastinum to the left.

Closed drainage was instituted for tension pyopneumcthorax. There was transient improvement and air was expelled from the closed drainage system in large quantities; then, the purulent discharge became thicker.

Open operation on the sixteenth day after admission (Dr. H. Neuhof) revealed purulent exudate throughout the entire pleural cavity. A large bronchopulmonary leak was found due to perforation of an abscess of substantial size.

The patient died a few days later and post-mortem examination (No. 10316) confirmed the surgeon's observations.

Case xii. *Multiple Encapsulated Empyemas Following Suppurative Bronchopneumonia.*

E. H., 355639, a male, aged twenty-two, was admitted August 10, 1933, with a history of an aching low right anterior chest pain of two weeks' duration aggravated by breathing or coughing. This subsided in a few days to be followed by a slight non-productive cough. A sharp sticking pain appeared in the right chest with a frequent cough productive of a moderate amount of yellow mucoid sputum.

Physical examination of the lungs showed the right chest to be splinted. There were flatness, egophony and distant to absent breath sounds on this side posteriorly. The temperature was 101° F.

Roentgen examination revealed evidence of a pleural effusion, encapsulated, at least in part, posteriorly.

Aspiration on August 18 revealed thin turbid fluid with occasional gram-positive cocci. The patient was treated by repeated potain aspirations but in two and one-half weeks the fluid became thick, the patient began to have paroxysmal cough with expectoration, for the first time, of large amounts of purulent fluid. A phlegmon of the chest wall appeared at the site of the aspirations. A posterior thoracotomy was performed on August 28 and a series of encapsulated empyemas were found over the posterior aspect of the lung from diaphragm well up toward the apex. Blowing fistulae were heard but were not visualized.

On September 3 roentgen examination revealed an anterior encapsulation with an area of rarefaction and a fluid level in its upper part.

On September 5 this pus was removed and a large blowing bronchial fistula was seen close to the costophrenic sinus. A second loculation was evacuated through the same incision. The chest condition cleared up completely but a cerebellar abscess appeared and the patient died. No post-mortem examination was obtained.

Case xiii. *Perforated Lung Abscess: Infrapulmonary Empyema.*

F. F., 405736, a housewife, aged sixty-eight, was admitted March 13, 1937, stating that eight weeks before she became ill with chills, fever, and a temperature which rose to 106° F. She was delirious and toxic for three days and was told she had influenza. A low-grade fever persisted until the present time, with slight cough, very little sputum, no chest pain, but gradually progressing weakness and anorexia.

Physical examination of the lungs showed, on the left side posteriorly below the scapula, flatness, absent fremitus, absent breath sounds and voice sounds, but no râles.

Roentgen examination (Fig. 9) showed a homogeneous shadow in the region of the posterior mediastinal pleura reaching down to the diaphragm which suggested a pleural encapsulation.

Operation (Dr. Neuhof) revealed "a large collection of pus sharply encapsulated between the arched surface of the lower lobe and apposed surface of the diaphragm. The cause was seen to be in a ragged, small, perforated abscess on the undersurface of the lower lobe in its mid-portion. There was a small bronchial communication."

Culture of the pus revealed pneumococcus Type vii.

Case xiv. *Ruptured Lung Abscess: Multiple Loculated Pyopneumothoraces.*

B. F., 403402, a housewife, aged thirty-two, was admitted January 12, 1937, complaining of cough and fever for three weeks. The episode began with frequent chilly sensations and malaise. After remaining ambulatory for five days she went to bed with a temperature of 106° F. Her cough was now more severe and was productive of a yellow sputum. Her condition was diagnosed as pneumonia. The temperature gradually subsided, the cough became less frequent and less productive. Five days before admission she experienced a sticking pain on the left side of the chest on coughing and on deep inspiration. This persisted until

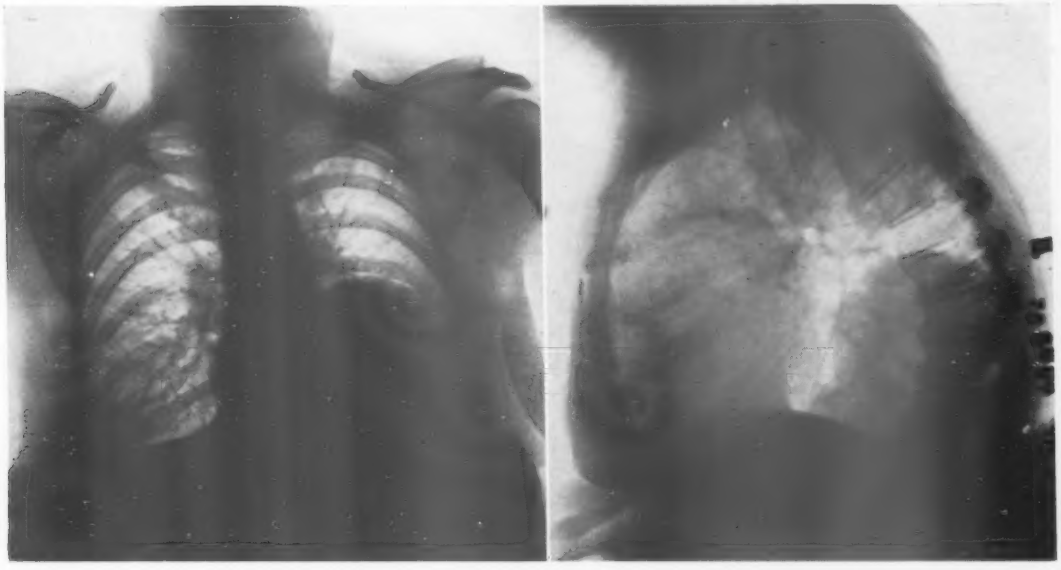


Fig. 9. Case xiii. Left posterior paramediastinal collection found, at operation, to be infrapulmonary.

admission. One day previously the attending physician aspirated a quart of yellow fluid from the left chest. Sputum typing at Harlem Hospital revealed pneumococcus Type iii.

Physical examination of the chest showed diminished motion on the left side. Over the lateral thoracic wall on this side there was an area of fullness and slight tenderness but no heat. There was flatness over the lower half of the chest with dullness-to-flatness above. There were absent breath sounds below and diminished bronchovesicular breath sounds above. There was slight dullness at the right base with occasional râles. The heart was displaced to the right but otherwise showed no abnormalities.

Roentgen examination on the day of admission, January 12, showed evidence of a

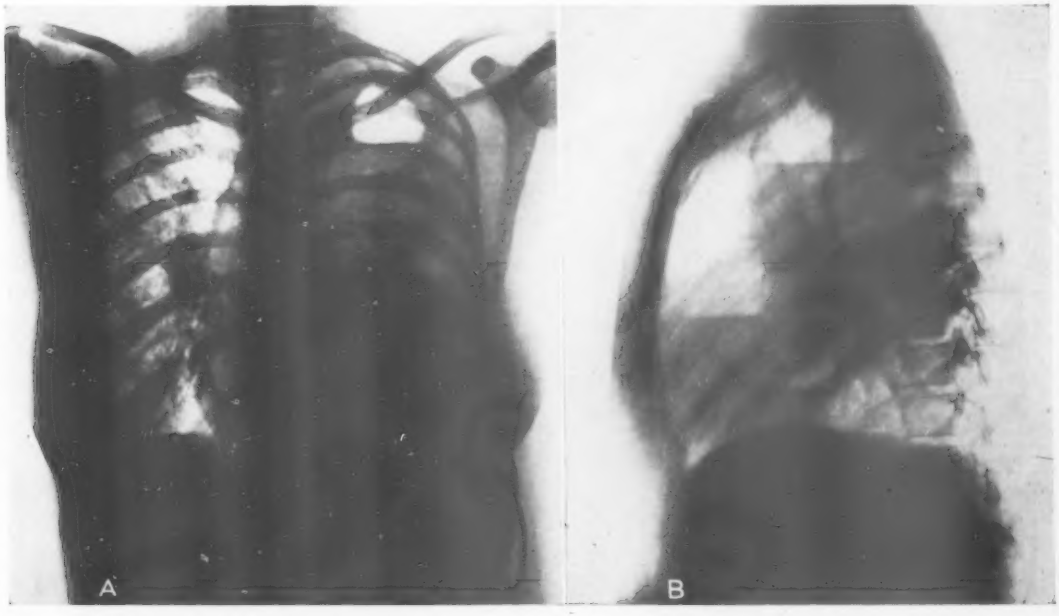



Fig. 10. Case xiv. Multiple loculated pyopneumothoraces due to double perforation of a lung abscess.

massive left pleural effusion with displacement of the heart to the right. Two hundred cubic centimeters of clear fluid were then aspirated from the left chest from which a pneumococcus Type III was cultured.

On January 22 roentgen examination showed a fluid level to be present in the upper portion of the previously homogeneous density.

On January 25 (Fig. 10) numerous fluid levels were found to be present.

Operation at this time (Dr. Neuhof) revealed a considerable collection of pus with air escaping in bubbles. The collection extended from diaphragm to subapical region. In the axillary region there was a series of gelatinous septa. The cause of the pyopneumothorax was found to be a double perforation with an inch of lung between. In a 2-inch zone about them the lung was soft and mushy to feel. At the upper point there was a large bronchial fistula and the lung was definitely necrotic for a circumscribed area about it.

Dr. Neuhof's comment was as follows: "Reconstructing the pathology, I would picture the following: Suppurative bronchopneumonia in a bronchopulmonary segment whose base at the pleural surface was 2 to 3 inches in each diameter. An area of necrosis in its midportion with probably some vascular occlusion to account for the considerable zone of necrosis without bleeding. Perforation into the pleural cavity partly directly, partly by way of reaming beneath a thin shell of lung to a point of exit at a lower level."

Case XV. *Bronchial New-Growth: Suppurative Bronchopneumonia: Recurrent Empyemas.*

S. B., 406101, a male, aged forty-eight, was admitted first in 1934 with a sharp pain in the right upper quadrant and cough. The pain slowly disappeared but weakness and dyspnea on exertion persisted. The patient ran a mild fever on admission up to 101.5° F.

Bronchoscopy revealed an extrabronchial or submucous growth compressing the right main bronchus 1 cm. below the origin of the upper lobe bronchus. There was secondary infection behind the obstruction.

A phlegmon of the chest wall developed. This was evacuated and further thoracic exploration revealed an extensive infrapulmonary empyema. A bronchopulmonary fistula was heard but its site was not demonstrated.

The sinus tract opened and closed many times during the next three years.

The patient was re-admitted on March 22, 1937, with sharp pain in the axillary portion of the left chest. Cough was minimal but there was expectoration of a small amount of greenish, odorless sputum daily. The temperature ranged between 98° and 102° F.

Physical examination of the chest showed the right chest to be the site of the previous thoracotomy. There was dullness at the left chest posteriorly becoming flat at the base. At the base fremitus was absent, breath and voice sounds were absent.

Roentgen examination showed evidence of a loculation in the upper left axillary region with a fluid level and a diffuse density at the base suggesting further loculations.

Operation revealed a loculated pyopneumothorax at the posterior axillary line on the left. This cavity was found to communicate via a narrow neck with another loculated pyopneumothorax high up in the axilla. A bronchial blow was heard but the site of the fistula was not identified.

## REVIEW OF THE FINDINGS OF ROENTGENOLOGIC IMPORTANCE

These cases have emphasized the following considerations of roentgenologic interest:

1. In its early stages suppurative bronchopneumonia has no differentiating features from other forms of bronchopneumonia. In the mild cases resolution takes place promptly. The severer forms of the disease are not common except in epidemics but are more frequent than is usually suspected due to the fact that the complications are not always recognized at the time of the acute illness.

2. The irregular mottling that appears roentgenologically in the course of a bronchopneumonia may be due to the formation of numerous suppurative foci but may be due simply to an irregular resolution. Only the course of the disease permits their differentiation. Similarly, simple resolving lobar pneumonia simulates the irregular mottling produced by suppurative foci and cannot ordinarily be differentiated from it roentgenologically.

3. In spite of a very mild clinical course, repeated roentgen examinations may re-

veal abscess formation which may be solitary or multiple. The solitary non-putrid abscess, however, is uncommon. Usually cases of single lung abscess are putrid.

4. The presence of pulmonary cavitation is not incompatible with complete spontaneous resolution although recovery may be slow. The clinical condition of the patient is a much better guide to prognosis than the roentgen appearance.

5. The presence of an abscess is only surely indicated roentgenologically by a fluid level. The absence of a level, however, does not exclude an abscess; it may be filled with fluid at the time of examination.

6. Roentgen signs of atelectasis often appear relatively early in the disease and are then probably due to bronchial obstruction as a result of plugging by thick tenacious secretions. Persistence of the atelectasis is the result of shrinkage due to maintenance of this contracted state by an interstitial fibrosis. In these cases the affected lobe may appear homogeneously consolidated and so simulate lobar pneumonia.

7. Pleural involvement may take the form of simple effusion, general empyema, encapsulated empyema, encapsulated or general pyopneumothorax. The pathogenesis of these processes is not discussed beyond indicating that pyopneumothorax appears most often to be associated with a perforated lung abscess and bronchial fistula.

8. Loculated pyothorax, with or without a fluid level due to the presence of air, is common. Loculation may occur anywhere within the pleural cavity. Infrapulmonary and paramediastinal collections present most difficulty in diagnosis. The latter are usually demonstrated clearly in the lateral view but it is usually not possible to state whether the mediastinum is also involved. Parapericardial collections present the same difficulties. Infrapulmonary collections must be suspected in suppurative bronchopneumonia when the diaphragm appears abnormally high. The shadows of the lower lobe pneumonia, infrapulmonary collection and diaphragm are apt to merge. Displacement of the heart to the opposite side suggests a fluid collection. Pneumoperitoneum may be necessary to establish the position of the diaphragm, although on the left the position of the gastric air bubble may give the same information. Exploratory aspiration and operation often have to be proceeded with in spite of inconclusive roentgen evidence (Touroff[11]).

9. It is often not possible to state whether a cavity is pulmonary or pleural. Size and the amount of surrounding density are of no great practical value in the differentiation; the large cavities are often intrapulmonary while the small fluid levels may represent pleural loculations. Lateral and oblique views are of greatest value in localizing the process. If the shadow is due to a pleural collection there should be one position in which it is shown as a more or less semicircular shadow, base against the chest wall. Interlobar collections are also identified in oblique and lateral views.

10. Potain or diagnostic aspiration performed carefully should not permit the introduction of air into the pleural cavity. The presence of a fluid level, therefore, usually indicates a pulmonary cavity regardless of previous aspiration.

11. Even after adequate drainage of a pulmonary or pleural collection of pus, a similar bronchopneumonia may develop elsewhere in the lungs with its own set of complications.

12. Bronchial dilatation is a common accompaniment of the disease. It develops early but is not necessarily permanent. A cylindrical dilatation, for example, may be caused by paresis of the bronchial muscle. Bronchographic studies are of great value in recording the course of this complication.

13. The operative indication in suppurative bronchopneumonia is not discussed beyond recording the obvious conclusion that it should be based upon clinical as well as roentgen data. The roentgen finding of a fluid level, for example, is only part of these data.

14. The disease in children is essentially

the same as in adults although usually more extensive. Obstructive emphysema and atelectasis are apt to be prominent features in infants.

15. A complete roentgen examination, including roentgenoscopy and roentgenography in sagittal, oblique and lateral views, is essential for the diagnosis and localization of pulmonary suppurative disease.

I wish to express my gratitude to Drs. H. Neuhof, C. B. Rabin and their associates for making available the results of their meticulous work on the clinical, surgical and pathological aspects of the disease. Dr. Rabin has been particularly helpful in his constructive criticism of this present report.

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Vol. 40, No. 1

# ROENTGENOLOGIC DIAGNOSIS OF PLACENTA PREVIA

## INDIRECT PLACENTOGRAPHY*

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IT IS now more than five years since we began the use of a roentgenologic method to demonstrate the presence or absence of placenta previa in third trimester bleeding cases. Our interest was first aroused by the demonstration of the placental mass on a routine roentgenogram of the abdomen of a pregnant woman in whom the clinical findings were diagnostic for placenta previa. This case was described in detail in our first publication,[11] and with it we described a technical and diagnostic procedure which incorporated the use of a contrast medium instilled into the urinary bladder. In later publications[12] we reported a group of 35 cases of abnormal bleeding during the third trimester of pregnancy. The technical and diagnostic features had been elaborated, and the possibilities of the method were further defined. Since the object of this procedure is the roentgenologic demonstration of the placenta as a soft tissue mass interposed between the visualized urinary bladder and the presenting fetal part, we will refer to the method hereafter as "indirect placentography."

The technique of the procedure has remained essentially the same. However, it has been found advisable to prepare the patient by the administration of low colonic flushes in order to eliminate gas and fecal material from the rectum. Rectal distention will not always lead to error in diagnosis, but may produce abnormal findings which closely simulate the positive picture. Fecal distention of the rectum probably constitutes the greatest hazard in the roentgenologic interpretation. The film study is made on the Potter-Bucky diaphragm table, with the patient in the supine position. The urinary bladder is first catheterized, and a small quantity, 25 to 40 cc., of a contrast solution is instilled. The catheter is then withdrawn in order to eliminate it as a possible factor of distortion of the bladder outline. An abdominal compression band is used only to stabilize, not for compression. Attempts to improve the results by firm compression in order to force the fetus farther downward into the pelvis have been proved of no additional value, and may even lead to error. We still adhere to the anteroposterior film of the entire abdomen and pelvis, with the roentgen beam directed vertically over the lower abdomen. Smaller films to demonstrate only the pelvic region have been found adequate in most cases, but will not allow study of the contents of the upper uterine segment. The lateral film is of no additional value to demonstrate placenta previa. However, it will show the very interesting anterior protrusion of the bladder during the later stages of pregnancy, and is also of importance in the search for the placenta in the fundus of the uterus. The additional oblique film used by Aurelius and Schulze[1] has definite merit, and in difficult cases may be the only view to allow a roentgenologic solution.

In the interpretation of the films, greatest emphasis is placed on the demonstration of a homogeneous tissue mass between the presenting part and the margin of the bladder. Normally this space consists of the wall of the lower uterine segment, the deflection of the peritoneum between the uterus and the bladder, and the thickness of the bladder wall itself. The total diameter of these tissues is about 1 cm., and seldom exceeds this width on the roentgenogram. The central type of placenta previa practically always displaces the presenting part upward over the entire upper surface of the bladder, while the partial

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type shows a distinct tendency to depress one of the lateral horns of the bladder and displace the presenting part somewhat toward the opposite side. The definable mass in the partial is usually not as large as in the central type. We have now seen several cases of breech presentation in which a negative diagnosis could be definitely established. A case of transverse position with presenting arm shown us by Aurelius in which a diagnosis of placenta previa centralis could be made also lends support to the view that with further experience a diagnosis can be made if any portion of the fetus is resting against the concave surface of the placenta. Whether blood clots in the lower uterine segment can simulate the findings of placenta previa is still an unsolved question. It may be assumed that this is a possible explanation for some of the failures of the method, but why it should occur so rarely in such a large group of bleeding cases is confusing. Rigler[9] has had a case in which an abnormal head-bladder relationship was present on the first examination. Further bleeding with passing of clots occurred during the succeeding day, after which re-examination revealed a normal relationship. Similar experiences have been encountered in several other cases, so that this factor must be kept in mind in the differential diagnosis. As stated above, the presence of large fecal masses in the rectum, with or without gas, is more commonly a disturbing factor and can be readily eliminated by colonic flush. One of the patients included in our present report of pathologic cases in which a positive diagnosis was erroneous showed a very high position of the urinary bladder, with a fairly wide soft tissue space between it and the symphysis, somewhat resembling the upward displacement of the bladder in the male with hypertrophy of the prostate. In this film the bladder did not show the usual compression from the distended uterus, but rather gave the impression that it was pulled upward instead of being compressed downward and forward. The patient was a gravida V, para IV, and should have been further studied for possible abnormalities of the abdominal wall which might account for these variations. This would emphasize the fact that all possibilities must be carefully evaluated before a definite conclusion can be reached, and that there are still confusing findings whose significance must be established by further experience.

The diagnostic value of indirect placentography has now been demonstrated by many other investigators. Its application has been sufficiently extensive to allow a fairly accurate evaluation of its reliability. Further experience has brought forth several additional features, so that it is found to be more reliable and of wider applicability than was at first surmised. Difficulties in differential diagnosis can be eliminated by simple procedures. Special research has definitely established the normal findings in control patients. Further study of unusual forms of fetal presentation has produced evidence that the method is reliable, not only when the usual head presentation is present, but also in breech presentation, and in any type of presentation where a portion of the fetus lies in sufficiently intimate contact with the placenta to permit identification of its inner margin.

Rigler[9] and Litzenberg[6] at the University of Minnesota Hospital were the first investigators to confirm our findings, and by frequent consultations and liberal criticism gave valuable assistance in formulating the procedure. In some of their early cases they experienced difficulty with very high position of the fetal head, but they soon discovered that this was usually due to the presence of fecal material and gas in the rectum, and that it could be eliminated by the administration of a low colonic flush. Following this discovery they became firm converts to the method, and have used it successfully in about 40 cases. Litzenberg[5] speaks of it as follows:

We have used the method at the University Hospital, and have found it of great service as an aid to diagnosis, especially in those cases in

which the physical findings left us in considerable doubt. It has proved to be of particular value in those cases in which there was painless bleeding and therefore placenta praevia was suspected, but the x-ray picture showed the presenting part lying directly upon the injected bladder, therefore we knew that the bleeding, although painless, was not due to placenta praevia. We, too, were able to prove the correctness of the x-ray picture at delivery or operation. The method has proved to be invaluable.

It was in one of Rigler's cases where we first showed that the findings of placenta previa could be simulated by a presenting fetal hand.

Friedman and MacDonald[2] reported 2 cases of placenta previa studied by our method in 1934, and verified by delivery. Their report leaves some question of doubt as to the correct application of our diagnostic criteria. Their first case shows the head abnormally high for typical placenta previa, and the demonstration of gas and fecal material in the rectum leads us to suspect that these played their part in the displacement of the fetal head. Removal of the rectal material would have clearly shown a descent of the head to the position which we feel is typical of placenta previa. This case was delivered by version and extraction of a dead fetus one month after the study, and diagnosis at delivery was placenta previa centralis. Judging purely from the illustration, their second case would have been interpreted by us as negative for placenta previa, and here delivery by cesarean section demonstrated a low implantation covering the lower uterine segment, with no mention of its relationship to the cervical os.

We were greatly stimulated by the frank statement of F. A. Wahl,[13] abstractor of our first report, in which he concludes as follows: "Während Verff. die Methode sehr empfehlen, kann vom Ref. auf Grund zahlreicher eigener Erfahrungen dem Verfahren keine differentialdiagnostische Bedeutung beigemessen werden." The abstractor apparently wishes to convey the impression that on the basis of extensive experience, he considers the procedure unreliable in differential diagnosis. He does not state whether the opinion is based on experience with the method or with clinical material. It is of course necessary to know the basis for his position more in detail in order to ascertain its authoritative value.

Hundley *et al.*,[4] in their study of "Physiologic changes occurring in the urinary tract during pregnancy," comment upon the various methods of roentgenologic study of placenta previa, and devote a very brief discussion to our method. They observed that in 10 of 27 patients studied by intravenous urography "there was found a space between the shadow of the fetal head and the outline of the bladder which varied from 1 to 2.5 cm. in diameter. In none of the patients was placenta previa found, all having normal deliveries. Therefore, we do not feel that this finding is diagnostic of placenta previa." They show an illustration of one of these cases, but the reproduction is not sufficiently clear to allow further analysis. Several suggestions could be made to explain the discrepancies. However, in the complete absence of any elucidating information as to the duration of the pregnancies in question, the nature of preparation of the patient and the technique of the roentgenological study, these discrepancies can probably best be enlarged upon by the authors themselves. Their report was especially disappointing because we had fortified our first description of the normal findings by the scientific exhibit of Drs. John S. Lewis, Jr. and Edgar C. Baker at the meeting of the Radiological Society of North America at Atlantic City in 1933, in which they covered a considerable portion of the same ground as the above authors.

More recently, a number of accurately studied cases have been reported. McIver[8] applied the method in 9 cases of bleeding in which placenta previa was suspected. Three showed the findings of placenta previa and were proved by cesarean section. The other 6 cases which were diagnosed as negative for placenta previa were proved by normal delivery. McDowell[7]

reports 9 cases in which he made a positive diagnosis of placenta previa in 7 and confirmed this by cesarean section. He states that his negative diagnoses were equally reliable. Hall, Currin and Lynch[3] report 40 cases of bleeding studied by our method. Seven cases showed placenta previa, 5 were breech presentations, and 28 negative for placenta previa. They also make the observation which we have now repeatedly made that the study is applicable in breech presentation. They likewise comment upon the criticism made by Hundley *et al.* as having been made on an incomplete application of the method. The illustrations of McIver, McDowell, and Hall *et al.* are conclusive proof that these authors are applying the method correctly.

Aurelius and Schulze[1] of Ancker Hospital, St. Paul, in a personal interview have shown the application of the method in 23 cases with very satisfactory results. They have introduced as an innovation an oblique film of the lower abdominal region to supplement our usual procedure. In this way they were definitely able to diagnose one case of placenta previa centralis with the fetus in the transverse position, with one forearm presenting over the upper surface of the placenta. The linear shadow of increased radiotranslucency first described by Snow and Powell[10] was of distinct service in this case as demarcating the outline of the fetal forearm. We are under the impression that this line must represent the layer of vernix caseosa on the body surface of the fetus, since this is the ever present fatty substance which could give such a layer of decreased soft tissue density. In several other cases, the oblique film was of assistance in arriving at a correct diagnosis. They also had several cases of partial placenta previa where the findings checked closely with those described by us for this type of implantation, with a somewhat more lateral position of the placenta, a more marked depression of one horn of the bladder, and deviation of the fetal head to the opposite side.

The normal relationship of the presenting head of the fetus to the urinary bladder was described in previous publications. It was accepted as a reliable standard on the basis of findings in numerous uncomplicated as well as in bleeding cases where placenta previa was ruled out by clinical findings and at parturition. It was, however, apparent that the normal relationship of the presenting part of the fetus should be further studied, especially as to its constancy and reliability during the last three months of gestation. This study has now been made by Robbins at the Minneapolis General Hospital, and constitutes a part of the material for a post-graduate thesis. Only a preliminary report is permissible at this time, but the complete findings will be available with the publication of the thesis.

Robbins studied more than two hundred patients during the third trimester of pregnancy. These were chosen at random from the prenatal clinic so that they did not represent selected complicated cases. Each patient was submitted to indirect placentography, and wherever possible this was repeated during each of the three last months of gestation. For the purpose of the comparative study, the fetal head-bladder relationship described by Ude and Urner in the uncomplicated case was taken as the normal, and any which could not be thus classified as negative for placenta previa were considered abnormal. None of these patients were prepared by colonic flushes as we are now doing in pathologic cases.

The group of cases examined during the seventh month of gestation, or rather in the third month before parturition, was the largest of the three groups. Eighty-seven per cent of these showed findings consistent with the normal, 13 per cent were abnormal, and of these 5 per cent presented findings which would be consistent with those of placenta previa. The remaining 8 per cent of the abnormal cases would have been classified as undiagnostic studies because of too wide variations either from the normal standard or from the typical placenta previa picture, and would have been re-examined after routine preparation.

In the group studied during the eighth and ninth months of gestation no definite deviations from the normal standard were encountered, so that it was conclusively established that the normal standard is extremely accurate during the last two months of the third trimester. Since, according to the statistics of the University of Minnesota Hospital,[6] the average duration of pregnancy in placenta previa and ablatio placentae is respectively 252.7 and 246.4 days, these complications become clinical problems usually well along in the eighth or early part of the ninth month, so that they occur usually during the period of maximum accuracy of indirect placentography. The percentage error in the seventh month of gestation then becomes of minor importance. No doubt this error would be greatly reduced by a more careful preparation of the patient.

The previous report[12] of our experience with indirect placentography was based on a group of 35 cases of abnormal bleeding during the third trimester of pregnancy. Since that time the method has been applied in an additional 44 cases at the Minneapolis General Hospital, and in numerous cases in private practice. In reviewing the 44 cases, each was interpreted by the roentgenologist of our group independently of the clinical findings, and this interpretation was then compared with the clinical findings and with the end-result. The roentgenologic interpretation revealed 39 cases as negative for placenta previa, 4 of the central type, and 1 of the partial type. The clinical findings, with the observations at parturition, established only 3 cases of the central type of placenta previa, 1 of the partial type, and 40 as negative. One error occurred in the roentgenologic diagnosis on the positive side, none on the negative. In the case of the positive error, the clinical findings were so predominantly against the roentgenologic diagnosis that the case was delivered by bag insertion with otherwise normal delivery. Several of the negative cases were breech presentations where the presenting breech was clearly demarcated and constituted as reliable a landmark as the presenting head. Several additional compound presentations have also been encountered where the presenting small part of the fetus was identified below the head, so that positive errors should be avoidable when this complication is present.

The demonstration of the placenta in the upper uterine segment, as described by Snow and Powell,[10] may be of distinct aid in arriving at a definite conclusion. It is with this in mind that we adhere to the larger films which will demonstrate the entire uterus, both in the anteroposterior and lateral positions. With technical factors adjusted for maximum detail, the placenta is probably demonstrated successfully in many more cases than is otherwise possible. In our routine films we were able to show it only to a limited extent. The case of Aurelius referred to above illustrates the applicability of the findings of Snow and Powell in placenta previa with arm presentation, as was anticipated but not actually demonstrated by these authors. The line of increased radiotranslucency was demonstrated as demarcating the inner surface of the placenta.

It will be apparent from the foregoing discussion that we have arrived at a fairly accurate evaluation of the reliability of indirect placentography. If the study reveals a normal fetal part-bladder relationship, placenta previa can be absolutely ruled out. If the relationship is abnormal, provided that fecal material and gas have been eliminated from the rectum, it requires careful differentiation whether the abnormality is caused by a placental mass, by compound, or by other abnormal presentation. An occasional error in diagnosis will occur on the positive side, but the percentage of error can be kept at a minimum. When the entire group of bleeding cases is considered, the percentage total error is comparatively small. Our obstetricians have never been misled into cesarean section, but have often been strongly fortified to proceed with surgery

when we were able to confirm the clinical findings of placenta previa.

The complete cooperation of the obstetrician and the roentgenologist is essential for the successful determination of the location of the placenta. Careful correlation of the clinical with the roentgenologic findings is to be urged in all cases. We wish to stress again the warning that surgical procedures should not be carried out solely on the basis of indirect placentography. Where the clinical findings, including a very careful abdomino-rectal examination, are at variance, both examinations should be repeated. Correct evaluation of the roentgenologic findings can only be based on personal experience with the method. As such experience becomes more widespread among roentgenologists and obstetricians, the procedure will become correspondingly more popular. It cannot be denied that there is a definite demand from obstetricians for assistance in this part of their specialty, and that they are giving a kindly reception to roentgenologic aid. They are also keenly critical, and will coordinate this aid with their study of the case before making a final decision. Although roentgenologic opinion in these studies should be given independently of the clinical history and physical findings, nevertheless it should under no circumstances be taken as the only factor in determining procedure. It should be used by the clinician purely as a corroborative finding.

SUMMARY

1. We have attempted to analyze the experience of others with our method of indirect placentography, as found in the recent literature and from personal communication from some of our colleagues.

2. A preliminary report is made of the roentgenologic findings in more than two hundred cases of apparently normal pregnancies. These were studied in groups during the seventh, eighth, and ninth months of gestation. This has given a more comprehensive picture of the normal findings, and has helped to establish the normal standard.

3. An additional group of forty-four cases of third trimester bleeding is reported, with an analysis of the roentgenologic findings.

4. Additional advantages of indirect placentography have been discussed, especially its applicability to breech and other abnormal fetal presentations.

5. Proper preparation of the patient and a standardized technique have been found advisable.

6. We have again attempted to define the position of this method of diagnosis in the armamentarium of the obstetrician.

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# KLIPPEL-FEIL SYNDROME WITH UNUSUAL CLINICAL MANIFESTATIONS

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CONGENITAL anomalies of the cervical spine are not uncommon and in recent years have been repeatedly described. Klippel and Feil[5,6,7] first described a deformity of the cervical spine which now bears their name. This deformity consists of a congenital synostosis of the cervical vertebrae involving the second to sixth vertebral bodies. These are fused into a single bony mass with a complete absence of intervertebral discs. This deformity produces a shortening of the neck and limitation of certain neck movements, especially lateral bending of the neck. Flexion, extension and rotation movements are usually normal although cases have been reported in which all neck movements have been limited.

Numerous symptoms accompany these cases. Brailsford[1] briefly describes the Klippel-Feil syndrome and gives a review of some of the clinical findings associated with it. These may be torticollis, facial asymmetry, scoliosis of the dorsal spine, nystagmus, lesions of the nerves of the brachial plexus, spastic paraplegia, sphincteric disturbances, neurotrophic joints and deformities of the shoulder and bones of the upper extremity. Pytel and Schajewitsch[9] have published roentgenograms of some of these cases. Jaubert de Beaujeu and Bloch[3] described the Klippel-Feil syndrome in a girl seventeen years of age. In this case there was shortening of the neck, low hair line at the back, limitation of cervical movements, and the roentgenograms showed a synostosis of the upper cervical vertebrae. Other investigators have described paralyses of the hand and atrophy of the thenar eminence in association with deformities of the upper cervical vertebrae.

This paper deals with the report of a case of Klippel-Feil deformity with rather unusual clinical manifestations.

## CASE REPORT

W. M. C., Negro female, laboratory technician, aged twenty-eight. Early in May, 1937, she began to have a tight feeling in the left arm. This was associated with a stiffness and a "tired sensation" across the shoulders. The arm began to feel heavy, stiff and became difficult to flex at the elbow. She then noticed that the left arm was becoming larger than the right and that the left sleeve of her dress was uncomfortably tight. It became difficult for her to comb her hair when using the left arm. The enlargement of the left arm frightened her and she came to the emergency department of the Hospital. Massage and other treatment were instituted without noticeable relief. Two days later she sought further medical advice and was referred to the authors by Dr. W. S. Quinland. At this time she had been noticing the heavy, tight sensation for about five days. There had been no actual pain at any time. On physical examination the patient was found to be an apparently healthy young woman with a left arm 4 cm. greater in circumference than the right. Temperature, pulse and respiration were normal. There was some shortening of the neck, but neck movements were free in all directions. Examination of the left arm showed a firm generalized enlargement that could not be pitted on pressure. The impression gained was that the enlargement must have been of longer duration than the five-day period she had noticed it. There was no muscular paralysis or atrophy of this arm. All other findings were negative. Blood pressure was normal. Hemoglobin, erythrocyte and leukocyte counts were normal. Urine findings normal. Wassermann, Hinton and Eagle tests were negative.

The patient's past medical history included an attack of what had been diagnosed as meningitis at eight years of age. At that time she was ill for two years. When she began to walk seven months after the onset of her illness there was a torticollis which was gradually overcome during the next year and a half. At the age of eighteen she suffered an acute attack of appendicitis with subsequent appendectomy.

Roentgenological examination of the cervical portion of the vertebral column demonstrated

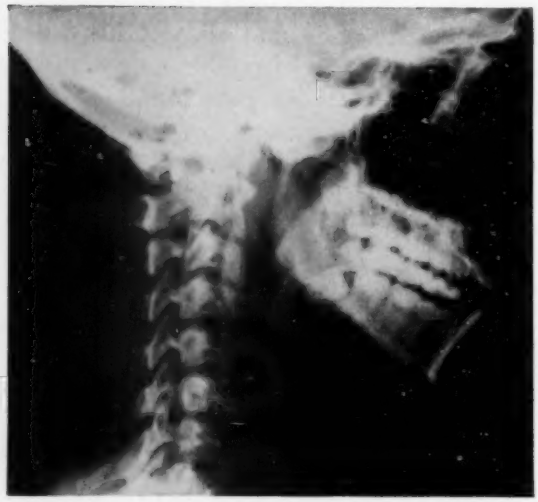

FIG. 1. Lateral view of a normal cervical spine.

complete synostosis of the 2nd, 3rd, 4th, and 5th cervical vertebrae. There was no apparent limitation of motion of the cervical region from a clinical standpoint. There was no roentgen evidence of a cervical rib. The intervertebral foramina were distinctly narrowed.

Treatment was initiated in the same manner as that used by Turner and Oppenheimer[8,10] in their treatment of referred symptomatology in the shoulder girdle and arm secondary to narrowing of the intervertebral discs in the cervical spine. The patient was seated comfortably and then the body raised by means of a suspension sling under the mandible and occiput. With the head in midline position, the shoulders were held by an assistant and slowly rotated each way as far as possible several times, the patient then being allowed to rest for a brief period. This procedure was repeated three times, at first daily and then at longer intervals. Within twenty-four hours of the first day's treatment there was a marked change in the arm. By the third day the enlargement had decreased by 2.5 cm. in the circumference of the left arm and the sensation of heaviness and stiffness in the extremity entirely disappeared. Treatments were discontinued after three weeks and there has been no return of the swelling, heaviness and stiffness during the past two months.

FIG. 2. Lateral view of cervical spine of patient W.M.C. showing Klippel-Feil deformity.

FIG. 3. Anteroposterior view of cervical spine of patient W.M.C. showing shortening of neck associated with the congenital synostosis.

## DISCUSSION

The analysis of the cause of the edema of the left arm and the type of treatment necessary for relief was quite difficult. The initial appearance of the limb suggested the possibility of some type of vascular or lymphatic obstruction. However, there was no cyanosis of the extremity and the temperature of the two arms was identical. In a study of the cervical spine made by Turner and Oppenheimer[8,10] numerous shoulder girdle and upper extremity abnormalities were noted but none observed where one arm had been enlarged in this

way. The usual findings in their series of cases were motor or sensory disturbances from nerve root involvement. Since in this case neither pain nor other sensory fibers were being irritated and no motor roots were involved, as far as could be determined, the edema seemed to be the result of sympathetic nerve involvement. Most

Fig. 4. Patient W.M.C. showing freedom of lateral and flexion-extension movements.

textbooks on neurology do not describe sympathetic fibers passing from the spinal cord along the roots of the upper cervical nerves. According to Cunningham,[2] the anterior primary rami of the first four cervical nerves, by means of the cervical plexus innervate the neck and the last four cervical nerves, together with a large part of the first thoracic nerve, supply the upper limb. Furthermore each of the first four cervical nerves as it emerges from the vertebral canal posterior to the vertebral artery is joined at the side of the vertebral column by a gray ramus communicans from the superior cervical ganglion of the sympathetic trunk.

Jelliffe and White[4] in their discussion of the vegetative nervous system state:

> Recent concepts concerning edema are undergoing such radical modifications that it is practically impossible to interpret the findings here outlined along these lines that regard all edemas as cell phenomena solely, independent of the action of the vegetative nervous system acting on the blood vessels. The studies of edema made by Fischer and others emphasize only the physico-chemical side of the problem. They neglect the role of the vegetative nervous system in the regulating mechanism.

In this case the authors have been led to conclude that the unilateral edema accompanying the congenital synostosis was

probably secondary to involvement of sympathetic fibers controlling the vascular bed and cellular structures of the left upper extremity.

SUMMARY

1. A case of Klippel-Feil syndrome with synostosis of the second to fifth cervical vertebral bodies fused into one bony mass is presented.

2. The unusual association of enlargement of one arm is described.

3. Possible involvement of cervical sympathetic fibers secondary to the synostosis is advanced as an explanation of the unilateral edema.

4. Rapid improvement was observed following suspension (traction) therapy.

5. The findings in this case support the contention of Oppenheimer and Turner that the flexibility of the cervical spine as a whole is not greatly disturbed as long as four or more intervertebral discs remain normal.

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# CARCINOMA OF THE UTERINE CERVIX

## A SURVEY OF TREATMENT AND RESULTS IN 1,491 CASES*

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RADIUM therapy has been employed at The Mayo Clinic in the treatment of carcinoma of the uterine cervix for the past twenty-two years, and today it ranks as one of the most effective methods of treating this dread disease. This study concerns patients referred to the Section on Therapeutic Radiology from 1915 to 1929, inclusive. Two patients were treated in 1915, and 24 were treated in 1916; since 1918 we have treated more than 119 patients a year. The total number of patients in this series is 1,491.

The general history, surgical records and special radiotherapeutic records furnished the material for this analysis, and although much of the material could possibly be interpreted in different ways we have attempted to do no more than bring out the facts as revealed by this method of study. Our daily observations and early results are encouraging both to us and to our patients, and the fact that in some cases these results do endure throughout the years should stimulate one to make it possible for all patients to have a chance for recovery and good health.

The age incidence is shown in Table 1, the division into decades showing that 63.7 per cent of the patients were treated between the ages of forty and sixty years, and 82.7 per cent between the ages of thirty and sixty years. The average age of the patients was forty-nine years, which shows that carcinoma of the cervix is truly a disease of the climacteric. It is of interest to note the average age for patients with early lesions was 59.3 years, and for those with borderline lesions 57.7 years. These data bear out our observation that patients who are many years past the menopause do not present themselves with the typical bulky or grossly infiltrating lesions. Bimanual palpation alone, therefore, may not reveal the actual extent of the primary lesion. The youngest patient in this series was twenty-three years old, the oldest eighty-one.

TABLE I

CARCINOMA OF UTERINE CERVIX (1915–1929)
Age incidence according to operability

| Type of lesion | Patients | Age, years | | | | | | | Average |
|---|---|---|---|---|---|---|---|---|---|
| | | 20–29 | 30–39 | 40–49 | 50–59 | 60–69 | 70–79 | 80–89 | |
| Early | 13 | 0 | 0 | 1 | 8 | 2 | 2 | 0 | 59.3 |
| Borderline | 85 | 0 | 9 | 18 | 28 | 28 | 2 | 0 | 57.7 |
| Inoperable | 981 | 16 | 153 | 330 | 330 | 135 | 16 | 1 | 49.8 |
| Modified | 412 | 12 | 122 | 147 | 87 | 42 | 2 | 0 | 45.7 |
| Total | 1,491 | 28 | 284 | 496 | 453 | 207 | 22 | 1 | 49.0 |
| Per cent | 100 | 1.8 | 19.0 | 33.3 | 30.4 | 13.9 | 1.5 | 0.1 | |

* Read at the Fifth International Congress of Radiology, Chicago, Ill., Sept. 13–17, 1937.

The importance of suitable classification of the lesions cannot be overestimated. From the standpoint of radium therapy, the extent of the malignant process when the patient presents herself for treatment should be the guiding factor in such a classification. Careful vaginal and rectal bimanual abdominal palpation with the patient in the dorsal position on a standard office examining table, and inspection of the vaginal cavity using some type of direct light and a Sims speculum with the patient in the knee-chest position, are the most satisfactory procedures to facilitate diagnosis and to determine the extent of involvement. To determine the presence of metastatic lesions, the inguinal and supraclavicular lymph nodes should be carefully palpated. The most valuable single laboratory procedure is roentgenographic examination of the thorax for evidence of metastasis to the lungs. In the presence of severe pain, and especially if the involvement tends to cripple the patient, a roentgenogram of the area may reveal metastasis to bony structures.

The classification of lesions adopted is a combination of the usual one employed in surgical clinics, with some additions, and the international classification recommended by the League of Nations: (1) early (operable) lesions, Stage I; (2) borderline lesions, Stage II; (3) inoperable lesions, Stage III or IV; (4) recurring lesions, Stage I, II, III, or IV (according to the extent of local or distant involvement); and (5) modified lesions, Stage I, II, III or IV.

All early lesions are limited to the cervix. In the case of borderline lesions, involvement extends beyond the cervix on the vaginal walls or into one or both broad ligaments. Inoperable lesions show two stages of involvement: in Stage III the lesion is definitely fixed, either through one or both broad ligament areas, and in Stage IV the primary lesion is usually fixed, with distant metastasis to the hymenal region, inguinal lymph nodes, lungs, and so forth. Recurring lesions are those which are operated on at The Clinic, and the same four stages of classification apply to them, the stage indicating the size of the recurrent lesion and the presence of metastasis. The last or modified group of lesions is made up of cases in which the primary lesion was treated or operated on elsewhere than at The Clinic, the gross appearance or anatomic landmarks thus having been "modified" by partial or incomplete healing. The stages in this instance designate the extent of the modification or

Table II

Carcinoma of uterine cervix (1915–1929)
Classification according to type of lesion and stage of involvement

| Type of lesion | Stage | | | | Patients | Per cent |
|---|---|---|---|---|---|---|
| | I | II | III | IV | | |
| Early | 13 | — | — | — | 13 | 0.9 |
| Borderline | — | 85 | — | — | 85 | 5.7 |
| Inoperable | — | — | 825 | 156 | 981 | 65.8 |
| Modified | 4 | 28 | 297 | 83 | 412 | 27.6 |
| Total | 17 | 113 | 1,122 | 239 | 1,491 | 100 |
| Per cent | 1.1 | 7.6 | 75.3 | 16.0 | — | — |

Table III

Carcinoma of uterine cervix (1915–1929)
Type of malignancy

| | Cases | Per cent |
|---|---|---|
| Epithelioma | 880 | 59.0 |
| Adenocarcinoma | 53 | 3.5 |
| Carcinoma (not specified) | 550 | 36.9 |
| Epithelioma and adenocarcinoma | 7 | 0.5 |
| Endothelioma | 1 | 0.1 |
| Total | 1,491 | 100 |

altered primary lesion and the extent of the secondary or metastatic deposits.

All cases are classified in Table II according to type of lesion and stage of involvement. The favorable groups of early and borderline lesions (that is, Stages I and II), were made up of 13 cases and 85 cases, respectively, or a total of 98 cases (6.6 per cent). Comparatively speaking, this is a very small number of patients. The majority of the patients were classified as having inoperable lesions, 825 having lesions of Stage III and 156 of Stage IV. "Modified" lesions represented all four stages of involvement. The 32 cases listed under Stages I and II in the modified group may be considered favorable from the standpoint of the size or extent of the altered primary lesion; in the remaining 380 cases in this group the lesions were grossly inoperable when first seen at The Clinic. There were no recurrent lesions in this group. In other words, 98 patients, or 6.6 per cent of the total, had lesions that were favorable for operation; 1,393, or 93.4 per cent, had lesions that were unfavorable for operation. The 32 cases listed as modified, Stage I and II, may be deducted from the latter group.

Microscopic study of the tissue removed revealed epithelioma in 880 cases, adenocarcinoma in 53, and carcinoma without specification in 550 (Table III). From these data it may be assumed that the majority of lesions or primary growths occurring in the uterine cervix are epitheliomas. In 883 cases the tumors were graded according to Broders' classification (Table IV), 5 being graded 1, 135 graded 2, 407 graded 3, and 336 graded 4. There were 743 epitheliomas of a high grade of malignancy (3 and 4), 140 of a low grade (1 and 2); in other words, 80 per cent of the lesions that were graded were of a high grade of malignancy.

Analysis of the chief complaint was tedious, and in some cases two or more signs and symptoms were recorded; only one, however, was selected. The tabular results were quite involved, but it was striking to note that for all groups the most common sign was extra-menstrual bleeding in some degree. For example, there were 13 patients with early lesions, and 12 of them complained of bleeding (92.3 per cent). Eighty-five patients had borderline lesions, and 81 (95.3 per cent) of them complained of bleeding. Of the 981 patients with inoperable lesions, 936, or

TABLE IV

CARCINOMA OF UTERINE CERVIX (1915–1929)

Grade of malignancy

| Type of lesion | Grade | | | | Not graded | Patients | Per cent |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | | | |
| Early | — | — | 7 | 1 | 5 | 13 | 0.9 |
| Borderline | — | 9 | 27 | 18 | 31 | 85 | 5.7 |
| Inoperable | 4 | 95 | 303 | 246 | 333 | 981 | 65.8 |
| Modified | 1 | 31 | 70 | 71 | 239 | 412 | 27.6 |
| Total | 5 | 135 | 407 | 336 | 608 | 1,491 | 100 |
| Per cent | 0.3 | 9.1 | 27.3 | 22.5 | 40.8 | — | — |
| Per cent of graded cases | 16.0 | | 84.0 | | | | |

TABLE V

CARCINOMA OF UTERINE CERVIX (1915–1929)
Hospital mortality

| Group | Total cases | Hospital mortality | Per cent |
|---|---|---|---|
| Early | 13 | 0 | — |
| Borderline | 85 | 0 | — |
| Inoperable | 981 | 14 | 1.4 |
| Modified | 412 | 1 | 0.2 |
| Total | 1,491 | 15 | 1.0 |

95.4 per cent, complained of bleeding; and of the 412 patients with modified lesions, 381, or 92.5 per cent, complained of bleeding. In other words, of the total of 1,491 patients, 1,413, or 94.8 per cent, complained of bleeding.

Treatment with radium was by the intensive, broken-dose method, employing in most cases the universal silver tube containing 50 mg. of radium sulphate (element) or 50 mc. of radon. The time of treatment and the interval between applications are very important. The filtration employed consisted of 0.5 mm. of silver and 1.0 mm. of brass. The vaginal applicator contained an additional 2 mm. of lead and 1 cm. of Para rubber. When patients were first seen, an attempt was made to outline a therapeutic procedure to meet the needs of the individual patient. Treatments, with very few exceptions, were given with the patient in the knee-chest position. In this way the applicator could be effectively placed and the results of previous applications estimated from time to time during the course of treatment, thus facilitating individual therapy. When necessary, the vaginal cavity was carefully cleansed and other measures

TABLE VI

RESULTS OF TREATMENT OF CARCINOMA OF THE UTERINE CERVIX BY IRRADIATION ALONE. PERCENTAGE SURVIVAL RATES ACCORDING TO TYPE OF LESION AND STAGE OF INVOLVEMENT

| Type of lesion and stage of involvement | Patients treated | Patients traced | Lived 3 or more years after treatment* | | Patients treated | Patients traced | Lived 5 or more years after treatment* | | Patients treated | Patients traced | Lived 10 or more years after treatment* | | Patients treated | Patients traced | Lived 15 or more years after treatment* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Patients | Per cent of those traced | | | Patients | Per cent of those traced | | | Patients | Per cent of those traced | | | Patients | Per cent of those traced |
| Early Stage I | 13 | 13 | 12 | 92.3 | 13 | 13 | 9 | 69.2 | 13 | 11 | 6 | 54.5 | 4 | 4 | 2 | 50.0 |
| Borderline Stage II | 85 | 81 | 57 | 70.4 | 85 | 78 | 47 | 60.2 | 48 | 42 | 13 | 31.0 | 19 | 16 | 1 | 6.2 |
| Inoperable Stage III | 825 | 760 | 292 | 38.4 | 825 | 753 | 224 | 29.7 | 463 | 423 | 57 | 13.5 | 170 | 157 | 4 | 2.5 |
| Stage IV | 156 | 142 | 18 | 12.7 | 156 | 138 | 9 | 6.5 | 87 | 77 | 3 | 3.9 | 14 | 13 | 0 | — |
| Modified Stage I | 4 | 4 | 4 | 100 | 4 | 4 | 4 | 100 | 4 | 4 | 4 | 100 | 1 | 1 | 1 | 100 |
| Stage II | 28 | 26 | 18 | 69.2 | 28 | 25 | 14 | 56.0 | 10 | 7 | 1 | 14.3 | 3 | 3 | 1 | 33.3 |
| Stage III | 297 | 271 | 68 | 25.1 | 297 | 267 | 53 | 19.8 | 167 | 150 | 17 | 11.3 | 70 | 62 | 1 | 1.6 |
| Stage IV | 83 | 74 | 4 | 5.4 | 83 | 74 | 3 | 4.0 | 52 | 47 | 2 | 4.2 | 7 | 5 | 0 | — |
| Total | 1,491 | 1,371 | 473 | 34.5 | 1,491 | 1,352 | 363 | 26.8 | 844 | 761 | 103 | 13.5 | 288 | 261 | 10 | 3.8 |
| Per cent | | 91.9 | | | | 90.7 | | | | 90.2 | | | | 90.6 | | |

* The 3-year group comprises patients treated 3 or more years prior to the time of inquiry, the 5-year group those treated 5 or more years prior to the time of inquiry, etc.

were employed to combat the usually existing secondary infection. Normal tissue was protected through accurate placement of the applicator and vaginal packing to maintain the applicator in position and to keep the adjacent vaginal walls away from the center of treatment.

As a rule, all patients received supplemental roentgen irradiation, with rays generated at 200 kv., following the course of radium therapy.

The hospital mortality rate is given in Table v. There were 15 hospital deaths, or a total of 1 per cent, there being no deaths in the early and borderline groups. This method of treatment can be applied in favorable cases with very little or no risk, and with only a small or slight risk in the inoperable or advanced groups.

The results of treatment are given in Table vi. The three-year group comprises cases in which the patients were treated three or more years prior to the time of inquiry, the five-year group those who were treated five or more years prior to the time of inquiry, and so forth. The favorable type of lesions, made up of both unmodified and modified lesions in Stages i and ii, showed rather satisfactory results. While the number of cases was small, it is encouraging to note that the number of good results was quite high. The unfavorable groups contain more cases and hence the figures are more reliable.

The difference in results in the unmodified groups is striking and may be attributed to the stage of the pathologic process when first seen on the radium service. The delay in the patients presenting themselves may be the factor controlling the difference in the results for Stage iii and Stage iv lesions. This may also be the factor in the percentage survival rate in cases of modified lesions of Stages iii and iv. In brief, patients with small lesions, which are limited to the cervix or show only slight extension and which are adequately treated, show the highest percentage survival rate both for the unmodified and modified groups of lesions. Patients with moderately large or extensive lesions have a definite chance of recovery on individual treatment; however, the percentage survival rate is definitely reduced.

Finally, it is encouraging to know that all patients accepted for treatment have a chance to become "cured"; as yet, however, there is no known method of making this estimation before treatment. Every case, therefore, is a challenge to the radium therapist, drawing heavily upon his store of skill and judgment, based on experience in the management of these cases, and equally on the equipment and facilities for treatment at his command.

## SUMMARY AND CONCLUSIONS

We feel that the intensive broken-dose method of radium therapy, followed by a course of roentgen treatment, after thorough study and planning of each individual case, offers the best results in this unfortunate group of cases. In this large series, extending over a period of fifteen years, although the great majority of patients (91 per cent) were in an advanced stage of the disease, of the entire number 26.8 per cent lived five or more years, apparently well following treatment. The possibilities of this form of treatment for early and borderline lesions can be appreciated when it is noted that 69.2 per cent of patients with lesions in Stage i were well at the end of five years, and 60.2 per cent of those with borderline lesions were well at the end of five years.

This form of treatment, of course, requires considerable individual care and experience; it also requires cooperation between patient and physician. The proper handling of emergencies as they arise during a course of treatment is an important factor. The fact that there is little risk to the treatment is attested by the fact that the hospital death rate for the entire series was only 1 per cent, the mortality occurring in the group with advanced lesions. There were no deaths at all during treatment in the early or borderline groups.

# CLINICAL OBSERVATIONS IN THE USE OF SUPER-VOLTAGE ROENTGEN RAYS BASED UPON SIX YEARS' EXPERIENCE*

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IF IT were possible at this time to compile and present an authentic monograph on supervoltage roentgen therapy, its value a year or two hence would be of doubtful moment. So much is learned each day—so rapid are the changes in the conditions with which we have to contend—so many scientists in various parts of the world are focusing their attention on the subject that the truth of today may prove to be the fallacy of tomorrow.

At a meeting of the Radiological Society of North America in Atlantic City in 1932, a paper[15] was presented which constituted a first report on preliminary cancer therapy with supervoltage at the California Institute of Technology. During the four and a half years which have intervened we have worked in earnest to amplify this investigation. With the assistance of Dr. C. C. Lauritsen, who designed and built the first successful supervoltage

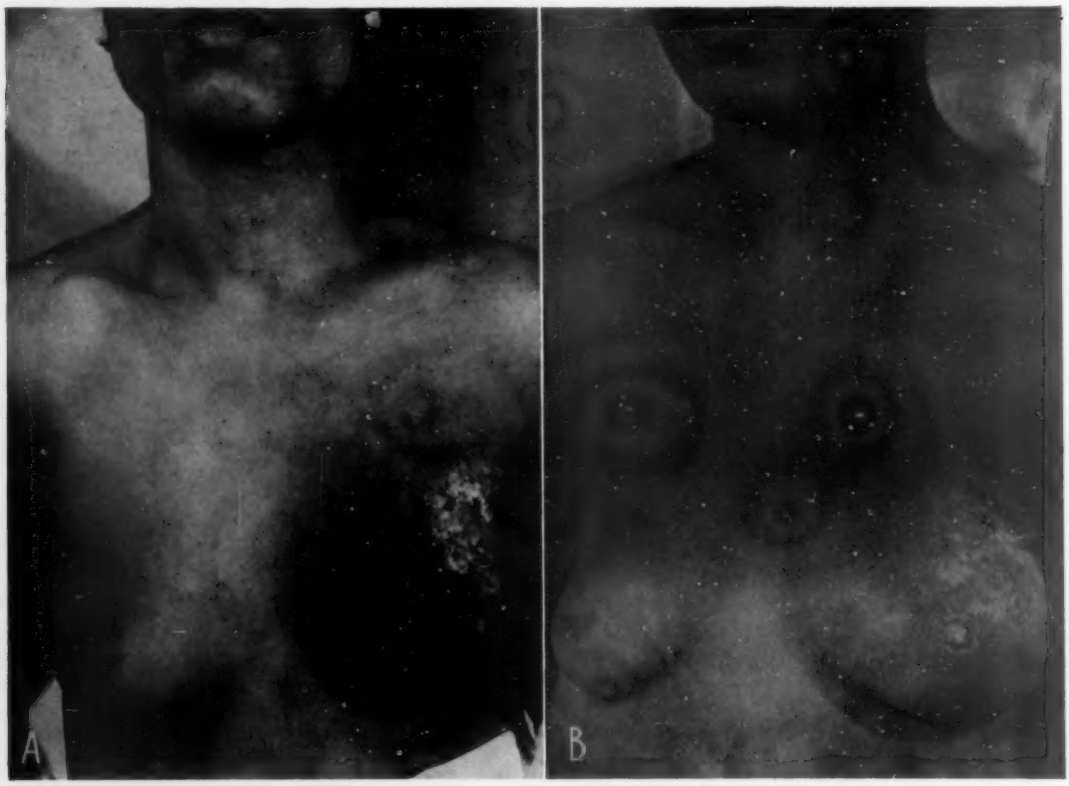


FIG. 1. Case 1. I. M., female, single, aged thirty. Carcinoma left breast. Patient had lump in left breast removed surgically; recurred six months later. *A*. Examination in September, 1936, showed extensive mass in the left breast with ulceration; massive axillary involvement. Received 1,800 r over two breast areas, and axillary and supraclavicular regions. *B*. May 10, 1937, breast entirely free of pathology and masses in neck smaller. Patient has also been sterilized.

* From the Oncological Service of Drs. Soiland, Costolow and Meland. Read at the Fifth International Congress of Radiology, Chicago, Ill., Sept. 13–17, 1937.

roentgen tube, and with the approval of Dr. Robert Millikan, the Institute's director, we installed, in our own clinic building, apparatus similar to that of the Institute. There are now several such installations successfully operating in various parts of the United States.

Fig. 2. Case 11. M. S., female, married. Far advanced carcinoma both breasts. Has been receiving serum treatment. *A*. October, 1936. Received 2,000 r (600 kv.) over each breast. *B*. April 23, 1937. Gradual improvement and no new activity.

Failla and his coworkers at the Memorial Hospital of New York gave, in 1933, a series of connected articles[2] on the relative effects of 200 kv. and 700 kv. roentgen rays and of gamma rays of radium, which dealt exhaustively with the physical and biological aspects of the subject. These articles were of the greatest value to all those who were interested in modern radiation therapy and deserve the highest commendation. At the time they were written, however, the clinical aspect of supervoltage roentgen rays had not as yet been fully demonstrated and only briefly alluded to before the American Medical Association at the 1933 meeting by myself and my clinical associates.[16] We would also call attention to more recent remarks along this line by Schmitz,[12] which bear out our own earlier conception of supervoltage radiation in cancer. Schmitz states:

The interpretation of the preliminary results of treatment with ultra-high voltage roentgen therapy presented can only be suggestive or speculative. They show a higher percentage of survivals after from 18 to 30 months than were obtained with 140 and 200 kv. max. roentgens, either with single massive applications or broken treatments. The final acid test will be the percentage of five-year cures. The higher percentage in early arrests of cancers of the cervix is due to the absorption of greater intensities (60 per cent) in the depth with 800 kv. roentgen rays than that produced by 140 or

200 kv. roentgen rays. However, one should remember that 200 kv. roentgen rays and gamma rays have proven of definite and positive value, and hence will continue to be used as in the past. It is in the large deep-seated, and massive cancers as those of the pelvic organs, the chest, the brain cavity, the oral cavity, and the large breasts, that 800 kv. roentgen rays are indicated.

Fig. 3. Case III. Mrs. J. H. S. Squamous cell epithelioma, Grade 4, of nasopharynx, with bilateral metastasis of neck. *A*. First seen on October 13, 1936. Large tumor filling nasopharynx with huge mass of cervical glands; far advanced. Received 150 r daily (600 kv.), with gradual disappearance of primary lesion and nodes. *B*. January, 1937. Pharynx was clear but there were new nodes in the neck; patient very weak; died three weeks later from cachexia.

During 1933, Lauritsen[5,6] of the California Institute of Technology, builder of the first successful supervoltage roentgen tube, presented very clearly the physical and biological aspects of extremely short wave roentgen rays. Lauritsen's terse comments were as follows:

In practical therapy we are usually dealing with large bodies and large beams and it is clear therefore that neither the air chamber nor the fly eggs nor the skin effect of a small beam give the radiologist any useful information beyond telling him the number of roentgens delivered in a given time. In the treatment of cancer the radiologist has no guide other than the skin reaction and general clinical observations. Great as is the uncertainty and variation in the erythema dose its importance to the experienced radiologist can hardly be over-estimated, for in most cases of deep-seated tumors the success or failure depends on the skin reaction, no matter what the wave length of the radiation is.

These are some of the reasons why radiology is still an art and probably will remain so for some time to come.

With this viewpoint I am in full accord.

About the time these statements of Lauritsen's were made, three other supervoltage installations were placed in opera-

Fig. 4. Case iv. C. S. Squamous cell epithelioma, Grade 3, of tongue with metastatic right cervical glands. First seen on July 18, 1936. Involvement posterior margin of tongue and anterior pillar of tonsil, which was recently removed. Received 150 r daily (600 kv.); total 3,450 r to right side and 1,800 r to left side. Throat cleared up but gland remained resistant. On January 15, 1937, 6.2 mg. radium implanted about gland, under evipal anesthesia; total 1,152 mg-hr. Made good progress. Seen on April 2, 1937, with no evidence of pathology.

tion: in Harper Hospital, Detroit, with Dr. Wm. A. Evans in charge; in Swedish Hospital, Seattle, Dr. Charles B. Ward, and in the General Hospital, Lincoln, Nebraska under the direction of Dr. Roscoe Smith.

Ward, Wirth and Rose,[23] writing of results secured at the Swedish Hospital, conclude as follows:

Emphasis is placed on the fact that this is a study of primary complete regression and lack of regression of disease following supervoltage roentgen therapy, for from six to eighteen months, and represents the total number of such cases so treated. No attempt is made to give end-results.

Treatment of certain advanced cases of carcinoma of the urinary bladder and cervix uteri by supervoltage roentgen therapy alone is justified.

In a personal communication to me, Dr. Roscoe Smith sums up his conclusions as follows:

Although the subject is open to controversy it is my opinion that supervoltage radiation is superior to 200 kv. radiation on deep-seated tumor tissue for the following reasons:

1. The effect on neoplasms closely resembles the changes produced by radium.
2. Preoperative irradiation of this type is a great advantage in early cases and surpasses other palliative measures.
3. The general condition of the patient improves more rapidly and the improvement is more apt to be permanent.
4. The blood changes are less severe.
5. Radiation sickness and skin erythemas are absent.
6. More rapid tumor regression is noted.
7. There is rapid relief of pain.

8. A combination of extremely high voltage radiation and one-third of a dose of low voltage radiation seems to produce more rapid recession on diffuse, superficial lesions.

All during the time that new supervoltage tubes were starting to operate in various widely separated localities, myself and my associates kept in contact with these institutions. Reports of tube trouble, corona discharges, inverse currents, and other difficulties reached our ears, while we ourselves were also struggling with the same problems. Fortunately, our close geographical connection to the California Institute of Technology made it possible for us to keep in touch with developments and proved of great service to us in working out these difficult problems. Lauritsen with his 2,000,000-volt transformers and a 30-foot tube, had run the gamut of potentials while maintaining a constant output of 15 r per minute. While he actually maintained treatment schedules at the high tension of 1,200,000 volts, he found that so many tube factors had to be contended with—gas production, inverse currents, corona discharges interfering with a steady emission, heavy charging currents, etc.—that he reduced his voltage to 850 kv. and later to 750 kv., which he found to be satisfactory.

With our own installation of an 800 kv. (peak) outfit, we found we could not operate on a constant potential stress over 595 kv., so we settled down to the original 550,000 volts first introduced in the California Institute of Technology, which we have since consistently maintained.

In view of the foregoing, we again desire to emphasize our belief that up to the present time it has not been proved practical to operate a tube in open air at 5 ma. with

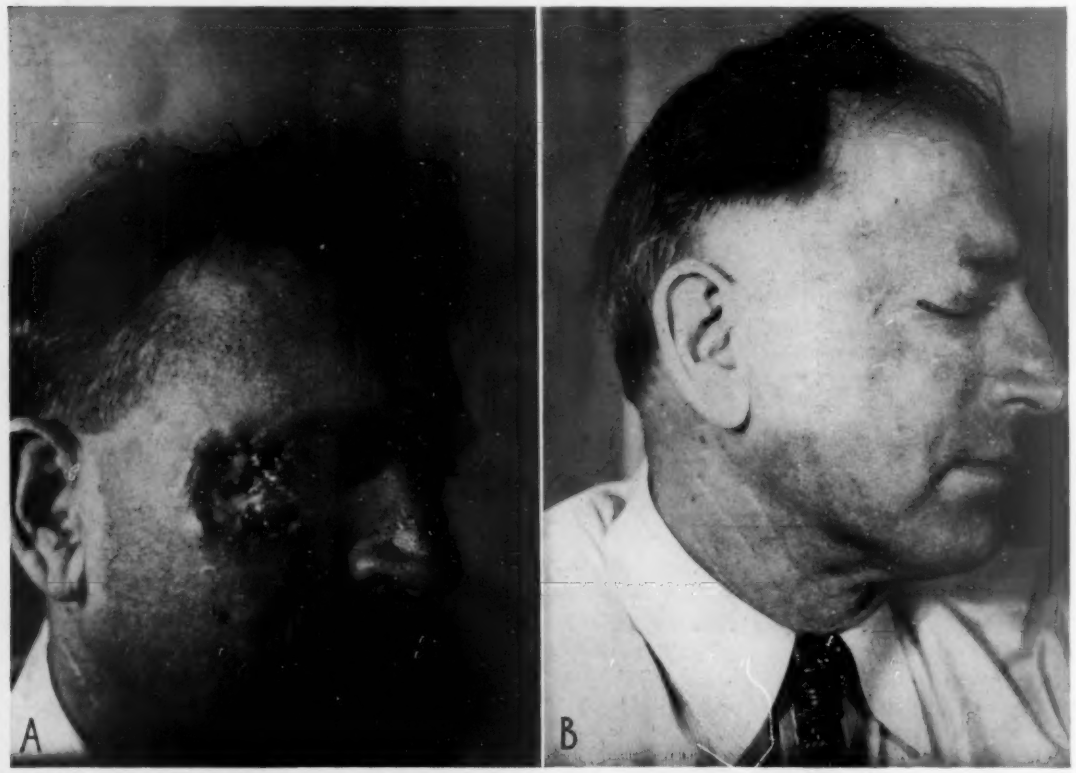


Fig. 5. Case v. H. S. B. Squamous cell epithelioma, Grade 1, right cheek. First seen on October 29, 1936. Irregularly shaped, deeply ulcerating tumor of right cheek, involving right outer canthus, 4 cm. in diameter. Received 150 r daily (600 kv.); total 3,000 r, over area including one-half of eyeball. Last seen on March 29, 1937—no pathology and normal vision.

any voltage above 750 kv. and get a steady uninterrupted measurable emission. We are also convinced that a voltage between 500 and 600 kv. will give a satisfactory and most dependable output. Undoubtedly (as has been previously stated) tube manufacture will improve and, as the voltage supply factor is comparatively simple, the future may yield the optimum of supervoltage roentgen-ray requirements.

Meanwhile, there are innumerable problems to be solved and much further experience is necessary with our present apparatus, which is both complicated and dangerous. We must avoid allowing our enthusiasm for the higher planes to encourage us to attempt reaching into the unknown. This is briefly alluded to in two papers.[17,18]

With reference to the clinical application of 700 kv. apparatus at the Memorial Hospital, New York, Herendeen[4] states:

> Such machines provide for greater depth doses and high intensities. Thus, in the treatment of certain deep-seated or radioresistant tumors, they can produce better clinical results with less damage to skin and normal structures. Although these machines will not necessarily replace the 200 kv. machines now in general use, it is our belief at this time that they will increase the range of usefulness of roentgen therapy, especially in the larger institutions where a large number of patients and a great variety of tumors are treated.

Fig. 6. Case VI. Mrs. L. H., aged sixty-seven. Epithelioma of forehead and nose. First seen in 1930. Treated with radium packs on forehead. In 1934 had new involvement on nose. Received radium and roentgen irradiation with 200 kv. In July, 1936, returned with nodular infiltration of nose, left eye, including part of orbit, and upper part of cheek. Received 150 r daily (600 kv.); 10×10 cm. area over face; total 2,850 r. Last seen on April 19, 1937; no evidence of recurrence.

It is of particular interest to note that all of the clinicians who have pioneered in roentgen therapy in the higher voltages have drawn nearly similar conclusions,

and, as these authorities have worked alone at great distances over the United States, their remarks are both enlightening and significant.

One of the pioneer workers in supervoltage roentgen-ray researches is Dr. M. A. Tuve, as well as his associates, Drs. L. R. Hafstad and O. Dahl. Tuve has contributed a great deal to our knowledge of the biological action of these ultrashort waves. I have had occasion to refer to his writings in several earlier communications and attention is drawn to some of his more important articles.[20,21,22]

Before the Second International Congress of Scientific and Social Campaign against Cancer held at Brussels in September, 1936, Dr. Francis Carter Wood[24] of the Crocker Cancer Institute of New York presented an article on roentgen therapy, in which he rather questioned the use of supervoltage apparatus, preferring, it appears, four separate 200 kv. units to one of 800 kv. capacity, believing he could obtain just as good results from the former, and have the economic factor of treating 4 patients simultaneously with the four single units. In a personal communication prior to the Brussels meeting, he stressed this point. As we were already treating 4 patients simultaneously with the higher voltage apparatus, I took issue with Dr. Wood's viewpoint as, obviously, there was no difference in the time period. On the other hand, the weight of evidence was distinctly in favor of the higher voltage, for, to obtain the same depth effect with the 200 kv. apparatus, it would be necessary to subject those treated to a time period multiplied by two. It is apparent

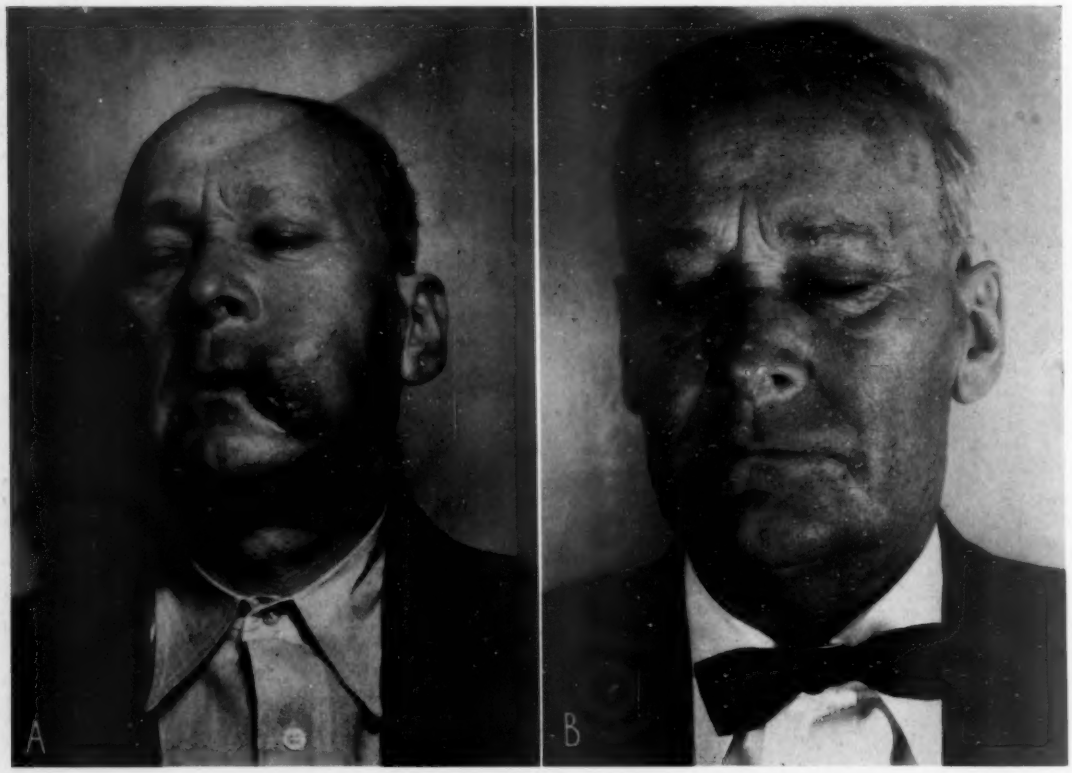


Fig. 7. Case vii. J. C. Epithelioblastoma of left cheek, Grade 2. First seen June 17, 1935; bulging, erythematous lesion 8 cm. in diameter and 5 cm. thick, left cheek; two large nodes left submaxillary region. Received 300 r (600 kv.) to one area daily; total 2,400 r, followed by interstitial radium needles; total 836 mg-hr., with practically complete disappearance of lesion.

that Dr. Wood has recently changed his point of view as, judging from recently published information, he is now about to make use of a new supervoltage tube which from the illustrations, is very similar to those already in operation.

Mudd *et al.*,[10] in conclusions based upon the treatment of inoperable and widespread carcinoma at the California Institute of Technology at Pasadena, state that:

Many instances of palliation in patients able to withstand full cycles of high voltage roentgen therapy have been noted. No reference has been made to preliminary report of clinical results, since a relatively small number of patients have been observed for a full three year period. In our opinion heavily filtered radiation at 600 kv., or higher, seems to offer better possibilities in the treatment of certain types of deep seated cancer than irradiation at substantially lower voltage. The results achieved by its use may be favorably compared to the effects produced by a 4 gram radium pack.

*Clinical Observations and Brief References from Case Reports.* The question frequently arises: Are better results obtained with the higher voltage apparatus than with the standard 200 kv.? During our cumulative treatment experience we have become more and more certain that supervoltage is a very distinct improvement over the lower voltages, yet we have made no positively affirmative statements in this respect. At the present time, however, there can no longer be any doubt. While we admit that there may be operators of standard 200 kv. apparatus who can perhaps approximate the average accomplish-

Fig. 8. Case viii. Mrs. G. E. R., aged forty-four. Hemangio-endothelioma left antrum with metastasis. Began to have protrusion of left eye two years ago. Had surgery to ethmoids, followed by complete blockage of breathing in nostrils. Has palpable nodes both sides of neck. Treatment with supervoltage roentgen rays, 300 r daily over sinuses; total 1,500 r to each of four areas and 1,500 r each side of neck. Markedly improved after six months' observation.

FIG. 9. Case IX. Mrs. K. H., aged sixty-two. Carcinoma right breast, Group III. Lump present twenty-four months, rapid growth. Metastases in axilla and supraclavicular area. Chest negative. Received 2,000 r over two breast areas, axillary and supraclavicular regions, October, 1936. April 20, 1937, no pathology.

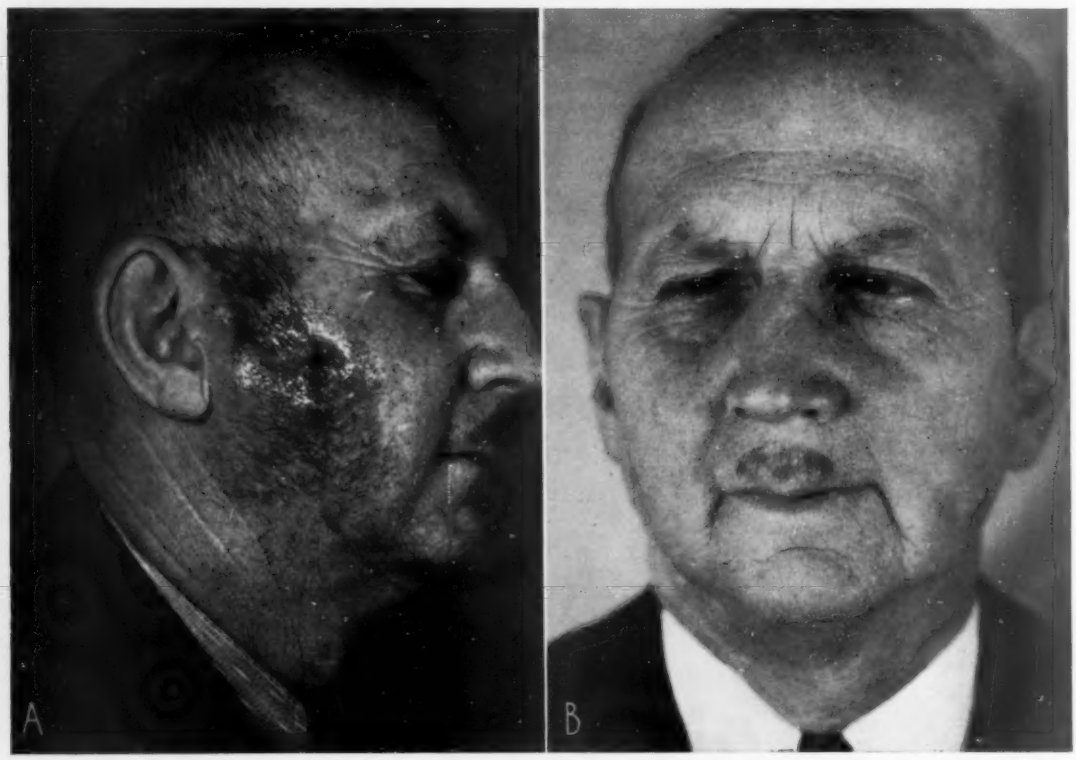


FIG. 10. Case X. B. L. Chronic ulcer with infiltration of entire right cheek. Biopsy showed squamous cell epithelioma, Grade 2. In March, 1937, received 150 r daily (600 kv.) to right cheek; total 3,000 r. May 11, 1937, ulcer healed, no pathology.

ment of supervoltage roentgen rays, we ourselves are observing clinical results which we had heretofore been unable to attain with the lower voltage equipment. Particularly is this fact true in patients with subsurface lesions or with distant recurrences. Broadly speaking, in cancer of the breast and uterus this has been seen devitalized mass. With cases of this character supervoltage roentgen rays have proved most satisfactory. Naturally, here also there is a limit, but a combination of supervoltage irradiation with adequate electrical surgery will give astonishing results in many such cases which may at first appear hopeless.

Fig. 11. Case xi. Mr. W. B. M., aged seventy-seven. First seen in August, 1935. History of rectal fistula in 1934, which biopsy showed to be malignant. Treated medically; bowel movements painful. Examination showed large ulcerating lesion with thick, everted edges, posterior margin of anus, approximately 12 cm. wide, 15 cm. long. Bilateral inguinal nodes. Received treatment with 600 kv., 4,200 r anal portal and 1,500 r each inguinal portal. There was marked regression of the lesion when last seen in January, 1936.

in a number of instances. In men, cancer of the mouth, tongue, prostate and rectum, has yielded an encouraging and increasing percentage of satisfactory results. Most outstanding, however, is that large group of insufficiently treated or radiation-resistant patients with infiltrating and ulcerating lesions about the face and neck. These have frequently been subjected to all sorts of applications through many hands, and one is confronted with a sclerotic, foul,

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# MULTIPLE GIANT CALCULI OF THE PROSTATE GLAND

## REPORT OF A CASE

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THE occurrence of giant prostatic calculi is of such extreme rarity that only very few references to this condition appear in the literature.

Young,[1] in his excellent paper on the subject, classifies prostatic calculi as "endogenous and exogenous, the former being those which form within the substance of the prostate and the latter those found in the prostatic urethra either having developed there in pockets, diverticula, etc., or having reached the urethra from the kidney, ureter or bladder." Clark[2] reports a case of complete replacement of the prostate gland by a solitary large calculus which weighed 58.5 grams. Ritch[3] recently reported a case of a single giant calculus associated with a much smaller stone. The case history presented below of multiple giant calculi simulating in appearance a complete calcification of the entire prostate gland is believed unique and of unusual interest.

### REPORT OF CASE

W. B., a colored veteran, aged fifty, was admitted to this Facility August 20, 1936. His past history was irrelevant except for a rectal operation of unknown nature performed in 1929. On account of his serious condition on admission, a complete coherent history could not be obtained. He complained of inability to urinate freely and of pain in the region of the bladder and right kidney, the present attack having begun with nausea and vomiting about three weeks previously. This had subsided prior to admission, but the kidney and bladder pain persisted, the latter being worse when the bladder was full, and associated with some dribbling and straining on urination.

Physical examination revealed a colored male, poorly nourished; arteries were moderately sclerotic; blood pressure, systolic 108, diastolic 90; temperature 98°F; pulse 110, respirations 22. The abdomen was flat and no masses were felt; there was rigidity of the lower abdomen, and some tenderness over the right kidney region posteriorly. There was no distention of either the abdomen or bladder. Patient was quite toxic. He voided in bed, apparently through a perineal sinus in the left side of the perineum, and also drained small amounts of pus through this opening. Rectal examination revealed no great enlargement of the prostate; the right lobe was stony hard, smooth, and tender; the left lobe was softer and not tender; the isthmus had a small hard mass like a stone. Blood count: red blood cells 5,300,000, hemoglobin 85 per cent, leukocytes 13,600 with 84 per cent neutrophiles. Urinalysis: amber in color, cloudy, specific gravity 1.012, albumin 4 plus, sugar none, white blood cells 3 plus, red blood cells 2 plus; Kahn and Wassermann tests were both negative.

Roentgen examination of the genitourinary tract was made on August 20, 1936, and the report was as follows: There are three very large irregular calcareous shadows measuring about 1 inch in diameter situated in the region of the prostate gland. These shadows more or less merge with each other and present the appearance of complete destruction of the gland. It is probable that in this case there is complete cal-

FIG. 1. Roentgenogram showing giant prostatic calculi.

FIG. 2. Specimen removed at autopsy showing giant prostatic calculi in pocket of prostate gland.

cification of the prostate gland. There is no evidence of calculus elsewhere in the genitourinary tract (Fig. 1).

On August 21, 1936, at 3:00 P.M. patient was given 550 cc. of saline and glucose intravenously. Several attempts to catheterize the bladder were unsuccessful, and he lost ground rapidly in spite of supporting treatment. The leakage continued through the perineal sinus; at no time was there any evidence of extravasation into the perineum. The abdomen remained rigid but there was no distention. His non-protein nitrogen on August 22 rose to 75 mg., urea nitrogen 86 mg., and creatinine 3.7 mg. His condition was too poor to warrant operative procedure, and he died at 6:00 P.M. August 22, 1936.

On autopsy no abnormalities were noted until the genitourinary tract was examined. The left kidney was normal in size and shape; on section, the calyces were increased in size and filled with cloudy urine; the pelvis and ureter were increased in size, the obstruction being present in the region of the bladder. The right kidney was smaller than the left, and on section only a small rim of kidney tissue was seen, the calyces and pelvis being markedly dilated and distended with cloudy urine. The ureter was

Fig. 4. Appearance of calculi after removal from pocket in prostate gland. Scale is in inches.

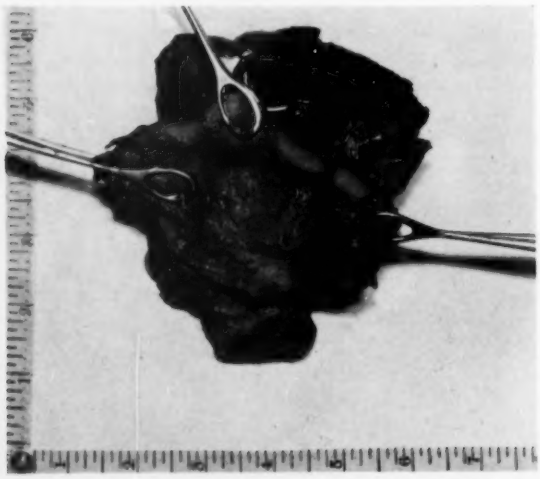

FIG. 3. Autopsy specimen showing large pocket in prostate gland after removal of stones. Scale is in inches.

dilated throughout its entire course, obstruction being noted, as in the left kidney, in the region of the bladder. The bladder was abnormal in shape, being elongated, and its wall was markedly thickened. On section, the only abnormalities seen in the bladder were the findings of acute and chronic cystitis. The urethra was of large caliber, measuring 1.5 cm. in diameter; it opened into a large cavity which measured 6 cm. in diameter (Fig.2) and which contained three large yellowish stones which completely filled the cavity (Figs. 3 and 4). One smaller stone which was extremely thin, was also present. These stones appeared to have caused the prostate gland to become extremely thin, prostatic tissue forming the walls of the sac.

Pathological diagnoses: bilateral pyonephrosis; marked dilatation of ureters and pelves;

marked acute and chronic cystitis; multiple stones of the prostate gland.

The aggregate weight of the four calculi was 49.42 gm. Individual weights were as follows: 20.27, 15.55, 12.91 and 0.69 gm. It is considered probable that these calculi were definitely of the exogenous type.

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# LARGE INTRATHORACIC THYROID

## CASE REPORT

*By* RALPH BOURQUIN MILLER, M.D.
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THE PRESENCE of aberrant thyroid glands growing within the chest, or the abnormal descent of the main gland, a lobe, or an adenoma are not uncommon findings. These abnormal locations of the thyroid have been variously designated as struma profunda, intrathoracic, retrosternal, or mediastinal goiter. The term, substernal thyroid, has been used to describe all of these conditions and it might be better to limit the term, substernal, to the abnormal descent of the main gland, the lobe, or an adenoma behind the upper portion of the sternum, and the term, intrathoracic goiter, to include aberrant glands growing within the chest or the more unusual presence of a very greatly enlarged gland or a portion of it.

This condition was first described anatomically by Haller[2] in 1749. Until more recent times, the clinical aspects of substernal thyroid and intrathoracic thyroid have not been well described, although, in 1830, Lingl[3] gave a very good clinical description of the condition. Clinically, substernal thyroids are of two main groups: one in which the thyroid assumes a position behind the sternum, and the other in which there are aberrant glands either attached to the main gland by fibrous tissue or completely separated thyroid rests within the thyroid cavity.[4,6] Substernal thyroids may be fixed or mobile. In the type in which a condition of mobility exists, the goiter may be forced from within the chest into the neck, or vice versa, following violent respiratory efforts or changes in position of the body. This gives rise to the condition known as "wandering goiter," "spring goiter," or "goiter mobile."

The incidence of retrosternally placed goiters varies from 12 to 30 per cent, as found in various groups of statistics. From January, 1917, to June, 1920, out of 4,006 thyroidectomies performed in the Mayo Clinic,[5] 13.5 per cent were partially substernal, and 25 per cent of these were found to be thoracic. Approximately 80 per cent of retrosternal thyroids occur in women between the ages of fifteen to thirty-five years.

The chief symptoms arising from the substernal type of thyroid are those of pressure on the trachea, esophagus, and the recurrent laryngeal nerves. Large intrathoracic goiters, however, may remain symptomless or show signs of mediastinal pressure.

The roentgen diagnosis frequently presents difficult differential problems.[1] The substernal intrathoracic goiter may simulate very closely a sacculated aneurysm of the ascending arch of the aorta, a persistent thymus, lymphosarcoma, Hodgkin's disease, mediastinal tumor, or more rarely echinococcus cyst. Generally, however, a careful roentgenoscopic examination of the patient in all positions and a careful history will help to make a proper diagnosis.

### REPORT OF CASE

J. H. M., aged fifty-two, came for examination on February 8, 1937, complaining of marked dyspnea, loss of weight, loss of appetite, and a sense of pressure in the upper thorax and neck. Except for pneumonia twenty years ago, the past history was essentially negative. The present illness began about three and one-half years ago at which time the patient complained of complete exhaustion, attributing this to "nervous strain." He made a trip East in an attempt to regain his health, but following this his condition became worse. He complained at this time of itching and the presence of pressure in the throat and right neck, violent coughing attacks during which times there was some expectoration of blood, shortness of breath, palpitation of the heart, and moderate dysphagia. He had a complete physical examination at this

time. It was thought that the hemorrhage came from the upper gastrointestinal tract rather than the throat. Except for an indefinitely described tumor between the lung and the right chest wall, the examination was negative. No diagnosis was made.

Examination of February 8, 1937, disclosed a man of late middle age who appeared very ill, showed evidence of recent loss of weight, had great difficulty in breathing, and was cyanotic. There was evidence of pathology in the right chest. The superficial veins over the upper abdomen and over the sternum were well visualized. A mass could be felt just above the sternum in the right supraclavicular region.

The roentgen examination in the postero-anterior view at 6 feet (Fig. 1) showed a very large intrathoracic tumor composed of three distinct masses, each surrounded by a thin wall of calcium. The uppermost mass was located centrally and extended about 1½ inches into both the right and left lung fields; the large mass occupied about two-thirds of the right lung field; a smaller mass was in the inner half of the left midlung field. The heart was displaced to the left and appeared to be of normal size.

The roentgen examination in the left oblique position at 6 feet (Fig. 2) showed one mass about 4 inches in diameter situated in the upper lung field anterior to the trachea. The trachea in this position was displaced backwards and was markedly depressed. The large mass in this view occupied almost the entire lower two-thirds of the right lung field. The left lung field in this view was entirely free of the tumor.

Fig. 1. Shows general appearance and size of large intrathoracic thyroid.

Fig. 2. Left oblique view shows upper mass and lower mass filling two-thirds of the right chest. Thin wall of calcium surrounding cyst-like tumors is visualized.

The roentgenogram taken with the Potter-Bucky diaphragm in the anteroposterior view in the supine position (Fig. 3) showed four masses surrounded by a thin wall of calcium, three of which have been described, the fourth being a smaller mass situated just above the base of the heart and in the left central area.

*Operative and Pathological Report.* The patient was sent to another clinic for consultation as to the diagnosis and possibility of removal of the tumor. It was not possible to make a definite clinical diagnosis. It was thought that the mass in the right supraclavicular region might be of malignant origin or possibly originate in the thyroid. The patient was sent to the hospital for exploration of the mass, and it was found to be the superior pole of a substernal

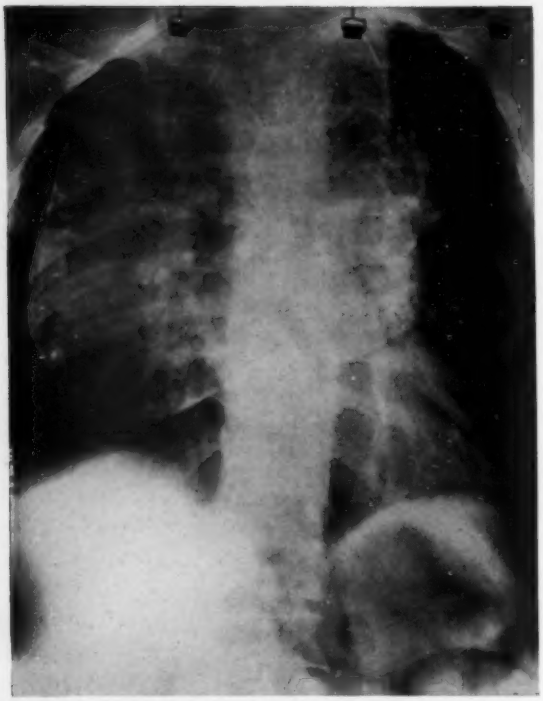

Fig. 3. Shows clearly the four distinct calcium-walled masses making up the large intrathoracic thyroid tumor.

thyroid. The right lobe of the thyroid was removed; no evidence of malignant disease was found, and upon palpating the intrathoracic mass with fingers along the sternum, it was found to be a huge intrathoracic goiter. Because of the definite rapid failing in the patient's general health, it was thought that an attempt to remove this tumor was advisable. This was done and the tumor was found to be entirely covered with calcium deposits and was firmly attached to the chest wall and to all the surrounding structures, particularly to the pericardium, the great vessels, and the pleura, and caused collapse of about two-thirds of the right lung and about one-third of the left lung. Under great difficulty, the tumor was completely removed. The patient died about one hour after the operation. The fatal outcome was thought to be due to the release of the tremendous intrathoracic pressure.

*Comment.* This case is presented because of the unusually large size of the intrathoracic thyroid, and because of the multilocular cystic appearance of the tumor, with all four apparent cysts being surrounded by a thin wall of calcium. A careful search of the reported cases of intrathoracic thyroid in the literature failed to reveal any that approached this tumor in size or showed the calcium-walled cystic formation as is presented in this case. A roentgenological diagnosis was difficult to make, and it was only through the report of the postoperative findings that a definite diagnosis of intrathoracic thyroid could be made.

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# THE MEASUREMENT OF GAMMA RAYS*†

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I HAVE been honored by being invited to open this symposium on the measurement of gamma rays. It is my understanding that we are here concerned with the measurement of these rays for their therapeutic application.

The gamma rays can be measured for therapeutic purposes by means of the biological, photographic, or ionization effects which they produce. For this purpose, however, the ionization method has proved the most accurate. Within the last few years, suitable apparatus has been developed for this purpose by various authors, by means of which determinations of the ionization current can be made within limits of a few per cent.

For the comparison of measurements it has seemed desirable to introduce a dosage unit. By analogy to the unit for roentgen rays, the "r" would be chosen. Since the adaptation of the methods of measurement used to determine this unit in the case of gamma rays would require extensive physical research, it has been customary to establish the dosage constant r/mg-el-hr. (roentgens per milligram-element-hour) by calculation from Eve's constant. The dosage constant is then specified as the dose in r which will be delivered by 1 mg. of radium at 1 cm. distance in 1 hour (usually with a filtration equivalent to 0.5 mm. of platinum). The knowledge of this constant permits the determination of the dose without direct measurement.

On account of the complexity of the physical phenomena associated with ionization by the rays from radioactive substances, there is still no complete understanding of the limitations of the measurements in the determination of the dosage constant. For instance, the effects of the material and thickness of the chamber wall, as well as the importance of the scattered gamma radiation, are differently evaluated by various authors.

Barrel chambers (standard air chambers), because of the large dimensions necessary when used in the field of gamma rays, have not led to very accurate results.[4,9,11,33,39,40,53,54] Nor does the small chamber with air-equivalent walls (thimble chamber), introduced by Fricke and Glasser,[12,13,14,15] permit a correct determination without limitations. The thickness of the chamber wall has been found to be especially significant (see below).

It has not yet been determined whether the great density of the air-equivalent materials relative to air at atmospheric pressure is significant with regard to the magnitude of the ionization current. It is, however, probable that, because of the loose arrangement of the atomic structure, the transition from the gaseous aggregate to the solid of the wall is without importance.[16] Also, theoretical considerations have shown that, because of the concentration of the points of origin of the secondary beta rays in the air-equivalent chambers, the measuring volume actually subtends a greater solid angle. However, the measured current is not too large, since the increase in angle is accurately compensated for by the decrease in the number of scattering centers.[1,2,36,46] A direct experimental verification of the above statement has not yet been obtained. With my colleagues, R. Schultze and U. Henschke, I have undertaken to investigate these matters, which are of fundamental importance not only for radium dosimetry, but also for the comprehension of the physical processes involved in the ionization by gamma rays. In the following pages our experiments are reported in some detail.

* Read at the Fifth International Congress of Radiology, Chicago, Ill., Sept. 13–17, 1937.

† Translated from the German by Edith H. Quimby, Memorial Hospital, New York City.

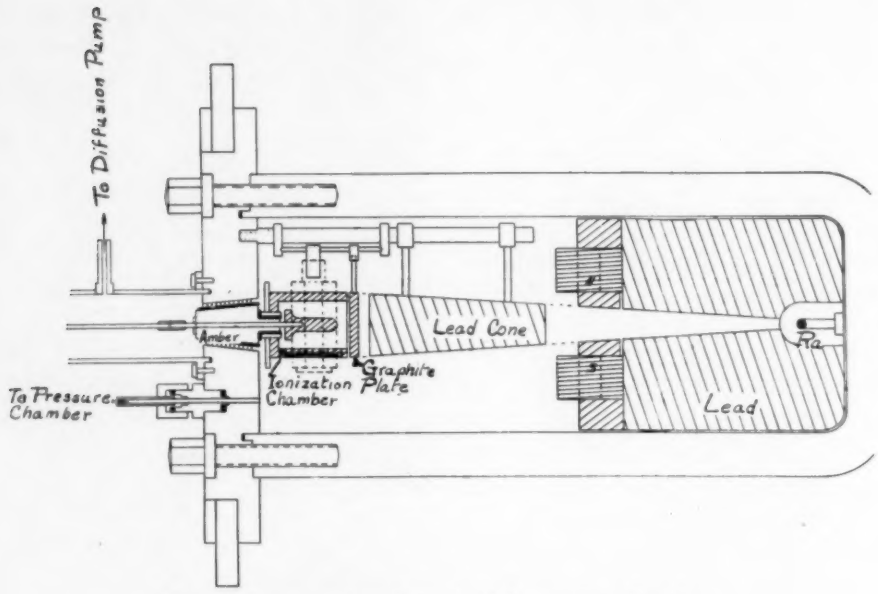


Fig. 1. Cross section through high pressure chamber.

The influence of the greater density of the wall material has been investigated in the first experiment, by comparing the electron emission of graphite and of air under varying pressures.

The apparatus is shown in Figure 1. In a high pressure chamber, in which the pressure could be raised to approximately 200 atmospheres, the radium source and the ionization chamber were placed 26 cm. apart. Surrounding the radium was a lead block with a conical opening, which pro-

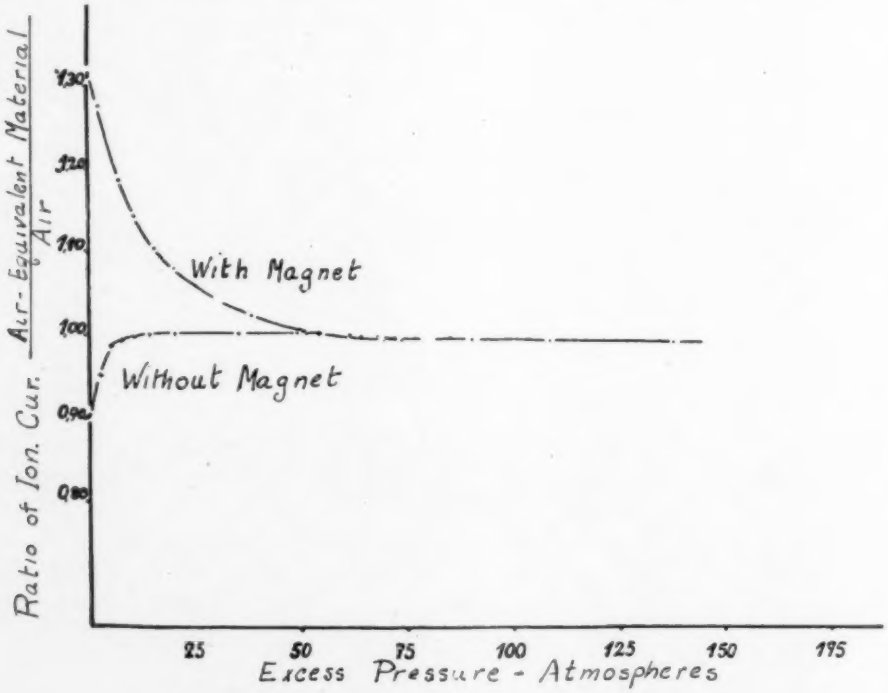


Fig. 2. Curve showing results of pressure experiment.

vided a narrow cone of rays. This was directed against the face of a cylindrical graphite ionization chamber having side walls 4 mm. thick. The face was closed with graphited tissue paper (7 $\mu$ thick). A 4 mm. plate of graphite could be swung in front of the tissue paper by means of an electromagnet. Because of the directional distribution of the Compton scatter, the ionization current in the chamber is produced mainly by electrons which are released between the radium and the chamber. The outer wall of the chamber was charged, the highly insulated inner electrode was connected, through a highly evacuated conductor 3 meters long, to a very sensitive aperiodic amplifier, which has been described elsewhere.[18,19,23] To determine the undesired radiation, a lead cone was swung into the beam of rays.[19] An electromagnet at the mouth of the conical opening in the lead block removed the primary beta rays and the electrons from the filter and the lead diaphragm from the measuring volume.

Measurements were made at various pressures, with and without the graphite plate in front of the chamber. Table 1 and Figure 2 show the results. From a pressure of 60 atmospheres up, the ionization current is constant, within $\pm$ 1 per cent.

The results with the lower pressures are in agreement with those obtained with air-equivalent chambers of varying wall thicknesses[5,11,18,19,20,33,39,50] and indicate, therefore, a similar effect for air and for air-equivalent materials. With diminishing pressure, the amount of material available for the production of secondary beta rays becomes smaller. Therefore fewer secondary electrons are produced in the air, and the ionization current becomes smaller than in the air-equivalent chamber. When the electromagnet is not used, the secondary electrons from the filter must be considered. The larger ionization current in this case is in agreement with earlier experiments[19] and is due to the position of the filter, directly over the radium.

By means of this pressure chamber experiment is demonstrated the unimportance of compression of the air, as is effectively the case with the air-equivalent chamber; at the same time the air-equivalence of our graphite is established. Because of the importance of this matter, however, it seems necessary to supplement this experiment with others. Accordingly, in a second experiment, the ionization in an air-equivalent chamber was compared with that in one which measured the roentgens in accordance with the internationally accepted definition.

Here the weakness of the definition is clearly evident. The requirement of measuring the ionization produced in 1 cc. of atmospheric air by full utilization of the

Table I

PRESSURE EXPERIMENT

| Without Magnet | | With Magnet | |
|---|---|---|---|
| Excess Pressure in Atmospheres | Ratio of Ionization Current with Graphite Plate to Current with Tissue Paper | Excess Pressure in Atmospheres | Ratio of Ionization Current with Graphite Plate to Current with Tissue Paper |
| 0 | 0.904 | 0 | 4.324 |
| 2.71 | 0.950 | 2.50 | 1.276 |
| 5.41 | 0.972 | 6.90 | 1.185 |
| 7.17 | 0.984 | 10.6 | 1.143 |
| 10.3 | 0.996 | 15.1 | 1.102 |
| 14.3 | 1.001 | 20.0 | 1.080 |
| 20.0 | 1.0025 | 26.5 | 1.060 |
| 35.0 | 1.001 | 30.0 | 1.040 |
| 54.0 | 0.999 | 38.0 | 1.023 |
| 73.4 | 1.003 | 49.0 | 1.001 |
| | | 51.0 | 0.998 |
| | | 61.0 | 0.999 |
| | | 64.0 | 0.997 |
| | | 67.8 | 0.997 |
| | | 69.0 | 0.987 |
| | | 73.5 | 0.986 |
| | | 79.5 | 0.987 |
| | | 84.5 | 0.995 |
| | | 90.0 | 0.985 |
| | | 108.5 | 0.988 |
| | | 139.0 | 0.990 |

secondary electrons cannot be experimentally realized. The barrel chamber used for the calibration of dosage meters does not really measure in accordance with the definition, because electrons emitted in front of and behind the measuring volume are not included in the measurement. Only because we are dealing in this case with an equilibrium condition, in which as many electrons enter the measuring volume as leave it (Holthusen and Becker) is it possible for the barrel chamber to measure in terms of r. This difficulty could be avoided if instead of the words "when all the secondary electrons are fully utilized" could be substituted "in a sufficiently large, uniformly irradiated space." This formulation has the advantage that it can be realized, by the creation of a uniformly irradiated space and the limitation of a definite volume for measurement within this space, as, for instance, by the tissue paper chamber of Eve.[6,7,8] Practically, the new definition does not entail any changes, because, on account of the equilibrium considerations mentioned above, it can be shown that the same dose is measured with a tissue paper chamber as with the barrel chamber.

The investigation as to whether a chamber with air-equivalent walls is suitable for measurements in r has therefore been carried out by comparison with a tissue paper chamber. For this experiment, it is essential to have a uniformly irradiated space, with elimination of all wall effects. This is possible only through the use of a sufficiently large room, and the placing of the radium sufficiently far from the chamber. A laboratory $5\times5\times4$ meters, and a gymnasium $24\times14\times8$ meters, were found to be too small, since the results were vitiated by beta-ray scattering from the walls (average distance about 3 meters), especially for large distances from the radium. The experiments were therefore conducted in the Deutschland Halle, which offers a free air space of $100\times50\times22$ meters between the galleries. The tissue paper chamber was supported in the middle of the hall by means of fishing lines (Fig. 3). The least distance from the chamber to the floor was 11 meters, which is certainly greater than the range of even the most penetrating secondary beta rays. The uniformly irradiated space could be realized over a range of radium-chamber distances, up to 40 meters.

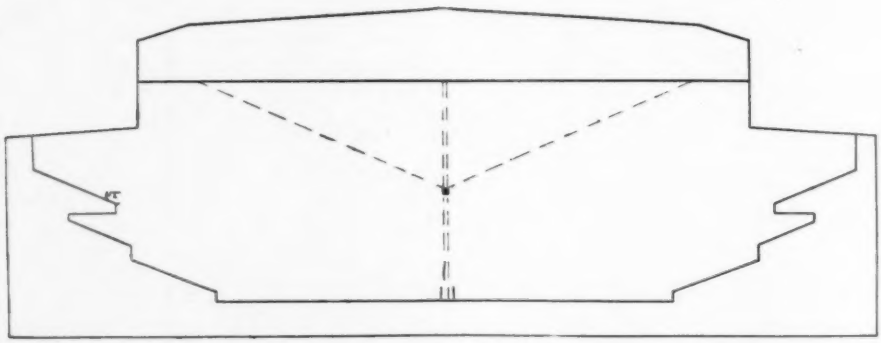

Fig. 3. Cross section through the Deutschland Halle, showing position of tissue paper chamber and of observer.

The chamber was a cube, 40 cm. on a side, constructed of graphited tissue paper 7 $\mu$ in thickness, on a frame of Pertinax rods 2 mm. in diameter. In order to avoid errors due to ionization in the conductors and in the electrometer, the electrometer system was built inside the ionization chamber. It consisted of a thin graphite rod to which was attached an aluminium leaf 2 $\mu$ in thickness, and was insulated from the graphited, grounded tissue paper walls by means of amber, with a guard

ring. The motion of the leaf was observed by means of a telescope, having a magnification of 40 times, situated on one of the side galleries of the hall, at a distance of 30 meters from the chamber. The source of gamma rays was a preparation of 2.2 grams of radium, filtered by 7 mm. of lead.

The comparison of the tissue paper chamber with the air-equivalent chamber was carried out in the following manner: A

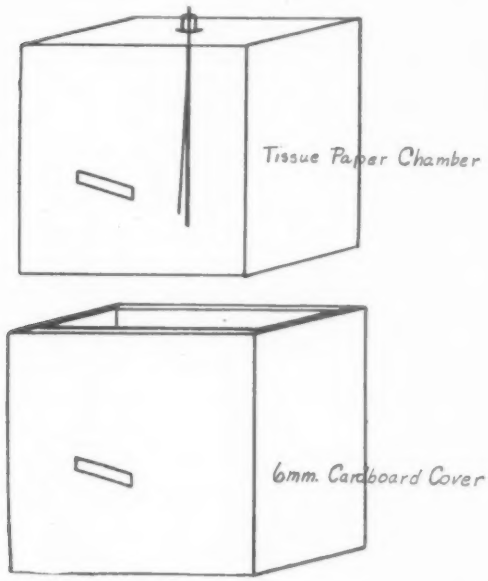


Fig. 4. Tissue paper chamber and cardboard cover for converting it into an air-equivalent chamber.

cardboard box with a wall thickness of 6 mm. was arranged so that it could be drawn up from below, over the paper chamber, by means of fishing lines. This cardboard box surrounded the chamber completely, except for openings for the observation of the electrometer leaf (Fig. 4). Measurements were made for various radium-chamber distances, with and without the cardboard box. By this means a high degree of accuracy in the measurements could be attained, since any variations in the leakage current (of the order of 40 ion pairs per cc. per second) or in temperature and pressure, had the same effect on both the tissue paper chamber and the air-equivalent chamber.

Table II and Figure 5 show the results of the measurements at various distances. The results obtained in the gymnasium have been included for the shorter distances. These are somewhat higher than those obtained in the Deutschland Halle, because of the secondary radiation from the walls. At a distance of 20 meters between radium and chamber, the ionization current is the same with and without the cardboard cover, within 1 per cent. This demonstrates that the air-equivalent chamber measures the dose in r, even in the gamma-ray region.

Table II

Comparison of Tissue Paper and Air-Equivalent Chambers

| In Gymnasium | | In Deutschland Halle | |
|---|---|---|---|
| Distance Radium to Chamber Meters | Ratio of Ionization Current in Tissue Paper Chamber to that in Air-Equivalent Chamber | Distance Radium to Chamber Meters | Ratio of Ionization Current in Tissue Paper Chamber to that in Air-Equivalent Chamber |
| 0.70 | 87.2 | 6.30 | 104.3 |
| 1.20 | 100.0 | 9.93 | 101.2 |
| 1.91 | 102.0 | 9.93 | 102.5 |
| 3.04 | 101.3 | 10.00 | 102.6 |
| 3.96 | 107.2 | 12.65 | 105.0 |
| 5.03 | 107.8 | 14.88 | 102.6 |
| 6.08 | 105.5 | 14.97 | 101.9 |
| 6.99 | 108.0 | 19.94 | 101.5 |
| 8.65 | 108.6 | 22.20 | 101.0 |
| 9.87 | 104.7 | 24.95 | 102.6 |
| 12.12 | 104.2 | 25.56 | 101.1 |
| | | 30.86 | 101.2 |

For distances less than 20 meters, the currents in the two chambers are different, since the space around the measuring volume of the tissue paper chamber is not uniformly irradiated. Comparison with the values for the air-equivalent chamber, which are in accordance with the inverse square law, show that the tissue paper chamber measures too low at short distances and too high at intermediate ones.

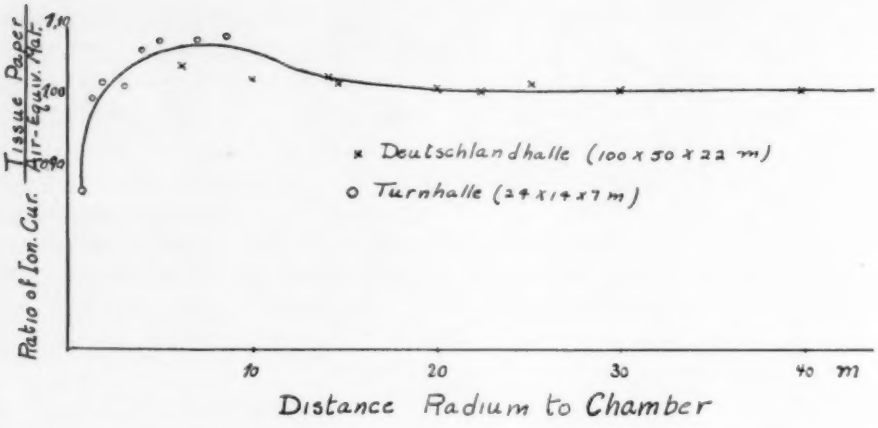


Fig. 5. Curve showing results of experiments with tissue paper chamber.

The reason for this behavior is shown schematically in Figure 6.

The secondary beta rays have an average range of about 3 meters in air. Hence, electrons released within this distance of the tissue paper chamber produce ions in it. According to our knowledge of the directional distribution of the Compton scatter, the secondary beta rays are emitted chiefly in the direction of the primary gamma-ray beam. The ionization in the tissue paper chamber consists, therefore, mainly of that resulting from electrons originating in the air space between the radium and the chamber. If the distance between them is less than 3 meters, part of the scattering space for equilibrium is lacking, and the ionization current is smaller than in the air-equivalent chamber, which supplies the necessary scattering material in its walls. At greater distances (about 6 meters), the necessary scattering space is available for the tissue paper chamber. Here, however, because of the inverse square law, there is a greater intensity of primary gamma radiation in the intervening air than in the wall of the air-equivalent chamber. The condition of a uniformly irradiated space is first attained at a distance of 20 meters, and the tissue paper chamber in this position measures the correct value.

On the basis of this value it is possible to calculate either the dosage constant r/mg-el-hr. or Eve's constant. Since, however, this experiment has proved the equality of the currents in the tissue paper chamber and the air-equivalent chamber, we have preferred to use the more reliable air-equivalent chamber for the determination of both constants.

As a result of the experiments with the tissue paper chamber, it is evident that a calculation of the value of the dosage constant for 1 cm., or any other distance, has meaning only when the space from which the electrons enter either the ionization chamber or the irradiated region is uniformly irradiated. At distances of less than 20 meters this can be accomplished only by enclosure in a sufficiently thick layer of

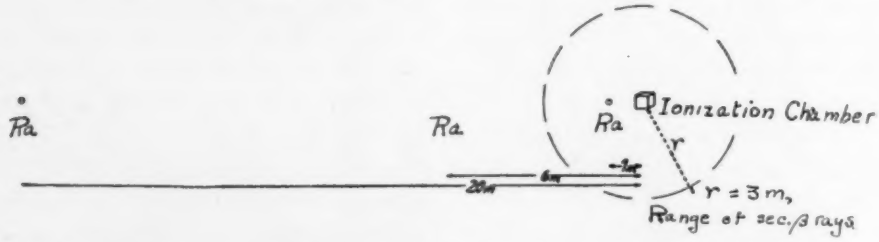


Fig. 6. Diagram showing scattering relations for various radium-chamber distances.

air-equivalent material. The necessity for this procedure has been repeatedly emphasized,[11,16] and is now once more clearly demonstrated.

By means of the two experiments described above, it has been shown that by means of the ionization method, with a suitable air-equivalent chamber, doses of gamma rays can be measured in r.

Table III

VALUES FOR DOSAGE CONSTANT OBTAINED BY VARIOUS AUTHORS

| Author | r/mg-el-hr. 0.5 mm. Pt | Chamber Material | Wall Thickness | Correction for Scattered Gamma Rays |
|---|---|---|---|---|
| Sievert (1934) | 7.55 | Celluloid | 2 | No |
| Murdoch and Stahel (1934) | 8.11 | Aluminium | 3 | No |
| Friedrich and Schultze (1934) | 7.8 | Graphite | 4 | Yes |
| Grimmett and Read (1935) | 9.4 | Electron | 1 | No |
| | | With celluloid shell | 4 | No |
| Kaye and Binks (1936) | 7.6 | Paper, wood | 4 | Yes |
| Glasser and Rovner (1936) | 8.8 | Graphite | 1 | No |
| H. Smereker (1937) | 7.74 | Aluminium | 3 | No |
| Mayneord and Roberts (1937) | 8.3 | Graphite | 4 | No |
| Minder (1937) | 7.98 | Graphite | 4 | No |

The determination of the above mentioned dosage constant, together with measurements for isodose charts, has been carried out by this method in recent years by various authors.[17,18,19,20,21,26,31,32,33,36,38,39,40,44,46,49,51,52] Values thus obtained are collected in Table III. In this table only the most recent value is given for any particular author. They vary from 7.6 to 8.8 r, that is, up to 15 per cent from one another, although it may be assumed that the measurement of the ionization current in any particular case is correct within a few per cent. For this reason, and on the basis of the available literature, the two experiments discussed in this paper, and other experiments which we have performed, it appears to us appropriate to discuss the reasons for the variations in the values obtained, and to set up conditions for the determination of the dosage constant and of isodose charts.

For the construction of the air-equivalent chambers, various substances of low atomic number have been employed, on the basis that, on account of the predominance of Compton scatter in the gamma-ray region, the material of the chamber has a negligible influence. This is, however, only conditionally correct. The variation in the ionization current in the graphite chamber constructed by us as air-equivalent, is greater, the less the filtration and the smaller the chamber. This is due to the fact that the ratio of ionization current to volume, for non-air-equivalent material, is dependent on the filtration and on the chamber size.[1,2,3,27,41,42] It can be shown, by means of an experiment described elsewhere,[27] that only when the wall material and the gas have the same electron emission is the current in the chamber proportional to the volume.[3,4,18,24,27,46]

Since the error due to the use of non-air-equivalent material may amount, in the case of aluminium, to more than 10 per cent, it is apparent that only really air-equivalent material should be used for the construction of chambers.

It is absolutely essential for correct measurements to have the chamber walls sufficiently thick to create around the measuring volume a uniformly irradiated space (see above). We have proposed in previous communications[17,18,19] a wall thickness of 4 mm. of graphite, since this is sufficient to eliminate the secondary beta

radiation from the filters and the surroundings. If this is not accomplished, errors will be introduced into the ionization current by scattering from the filters and from objects in the vicinity.[19,28,51] An additional danger is that with thin-walled chambers the ionization current is not proportional to the volume. Since the filter and the neighboring objects consist frequently of materials of high atomic number, whose secondary radiations can enter a thin-walled chamber, the same sort of error will result as if the chamber is not air-equivalent. For this reason, measurements with thin-walled chambers, in the body or in phantoms,[10,30,50] are correct only if the measuring volume is surrounded by a sufficiently thick layer of tissue or of phantom material, and if these materials have the same electron emission as air. If the electron emission is greater or smaller,[37,38] or if measurements are conducted at smaller distances from the radium than 4 mm., primary beta rays and secondary rays from the filter can enter the chamber. In this case the measured current is not proportional to the volume, and so cannot be calculated in r. However in such a case it is obvious that dosage cannot be measured directly with an air-equivalent chamber either. Since, moreover, the ions both in the ideal medium of the ionization chamber, and in the various materials of the irradiated regions, are produced by electrons, it seems to me that the relation between air dose and—let us say—tissue dose, can be specified only by means of a factor which must be experimentally determined.

Since the employment of chamber walls 4 mm. thick is absolutely essential in order to obtain comparable results, it is of little use to eliminate the absorption of the chamber walls for calculating the value of the dosage constant r/mg-el-hr., in contradistinction to Eve's constant. The absorption of the filter should not be corrected for, moreover, since for medical purposes it is desired to know the dose under the conditions of irradiation. This can be specified in roentgens only if the measuring volume and the irradiated tissues are both completely surrounded by about 4 mm. of air-equivalent material.

The definition of the roentgen requires the utilization of all the secondary electrons released in the air. According to this, it would be necessary to include electrons resulting from scattered roentgen or gamma rays.

This is not done in the measurement of r with the barrel chamber in the roentgen-ray region, because the range of the scattered rays is greater than the dimensions of the chamber. Even with the tissue paper chamber, it is extremely difficult to determine the effects of the scattered gamma radiation. It could only be done in the same way as in the research described above with secondary beta rays, but in this case it would be necessary, in order to obtain a uniformly irradiated space, to have a radium-chamber distance of at least 300 meters.

It appears, therefore, reasonable to adapt the definition of the r to experimental possibility, and to specify that scattered roentgen or gamma radiation shall not be included.

To obtain an approximate idea of the magnitude of the gamma-ray scattering in air, the ionization currents for the air-equivalent chamber were compared with the inverse square values for the same distances. It was found that the absorption of gamma rays in the air was compensated for by the scattering. Since according to the absorption coefficient given by Kohlrausch[35] the absorption by the air would be about 16 per cent, the magnitude of the gamma-ray scattering in air must be about this amount. In smaller rooms the gamma-ray scattering may be considerably greater, as has been found by Kaye and Binks[33] and Minder.[44]

To determine the magnitude and direction of the gamma-ray scatter by bodies in the vicinity, a chamber of graphite 4 mm. thick was constructed so that wooden blocks could be placed in front, on the sides, and at

the back. In the front wall, a conical opening was provided to permit the entrance of the direct beam into the chamber without absorption. The scattered gamma radiation from the front wooden cover amounted to 9 per cent, that of the sides to 5 per cent of the direct gamma radiation. That from the back was negligible. The value of the gamma-ray scatter by the wood in this experiment is of the same order of magnitude as that of the air in the previously described experiment in the Deutschland Halle.

by a lead cone, so that only the scattered radiation is measured (Fig. 7).

Therefore, the necessary conditions for the determination of the dosage constant are: air-equivalence of the material, sufficient thickness of the chamber walls, and the exclusion of scattered gamma radiation.

In the last column of Table III it has been noted whether or not the various authors adhered to all these conditions. It appears that only our own determination[18] in 1935, of 7.8 r, and that of Kaye and Binks[33] in 1936, of 7.6 r, satisfy the requirements.

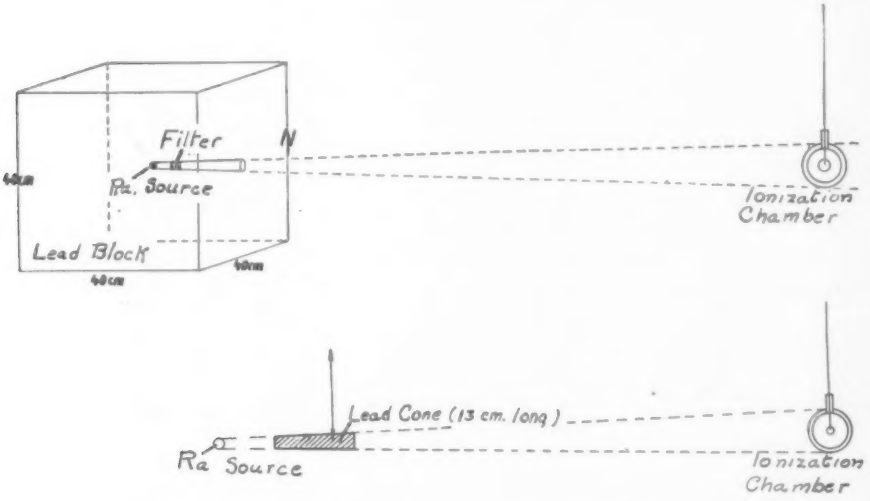


Fig. 7. Diagrams showing methods for eliminating the gamma-ray scattering.

Since the gamma-ray scatter is dependent to a high degree on the material, the size of the room, the radium-chamber distance, and the arrangement of the apparatus, the determination of the dosage constant should exclude this scattered radiation. Also in the definition of Eve's constant it is agreed that the scattered gamma radiation should not be included.[48]

This exclusion of the scattered gamma radiation can be accomplished either by shielding the radium with a large mass of mercury or lead, leaving a small cone for the useful beam, or by means of a differential method. In this case, the reading made as usual includes both the direct and the scattered radiation. The measuring chamber is then screened from the direct beam

These agree remarkably well, within the specified limit of $\pm 2$ per cent. The other values are, for the most part, higher, which we would expect on a basis of insufficient wall thickness (inclusion of secondary beta radiation from filter and surroundings), use of material of higher electron emission than air (aluminium, electron metal), or failure to eliminate the scattered gamma radiation.

In order to compare our value of 7.8 r with the available values for Eve's constant,[6,7,8,25,29,45,47] a recomputation on the basis of number of ion pairs was made. The value obtained for Eve's constant was $5.5 \times 10^9$ ion pairs per cc. per gram per second. Published values for this constant vary between 3.76 and $5.25 \times 10^9$; they are,

however, not comparable with each other nor with the value given above, since the absorption in the filter, and the value assumed for the elementary electric charge, vary. If, however, from the data in the various published experiments, the constant is recalculated, the effect of the filter being determined according to Kohlrausch's data,[35] and the value of the elementary electric charge being taken as $4.80 \times 10^{-10}$ e.s.u., the resulting values vary from 5.1 to $5.6 \times 10^{9}$, and are in excellent agreement with our own result.

## CONCLUSIONS

A critical review of the measuring requirements for the dosage constant and isodose curves, for gamma rays, shows that an adequate determination in roentgens is possible only with the use of an ionization chamber of air-equivalent material and sufficient wall thickness, and with the exclusion of the scattered gamma radiation. Under such conditions a dosage constant is obtained of 7.8 r per milligram-element-hour.

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# THE IONIZATION MEASUREMENT OF GAMMA RADIATION*

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IT IS unnecessary on such an occasion as the present, to dwell on the importance of being able to make, both accurately and conveniently, quantity measurements of gamma radiation in the treatment of cancer. The problem is of international standing and the International Committee for Radiological Units is fully alive to the situation.

By way of preamble, we may recall that in the light of present physical knowledge, the fundamental conception of the quantity of radiation received at a point in a medium is based on the amount of electronic energy which is absorbed per unit volume at the point in question. It is further accepted that a related measure of the electronic energy absorbed by any point in a medium may be derived experimentally from the ionization produced in a minute air cavity situated at that point in the medium.

For medical purposes, since the medium is commonly soft tissue, which has approximately the same effective atomic number as that of air, the air-ionization per unit volume is regarded as closely approximating in most circumstances to a measure of the quantity of energy absorbed by unit volume of tissue—a quantity which in radiation therapy is commonly called the "dose." Owing to the pitfalls of biological reactions as dosage indicators, it is difficult to provide definite proof of the assumption that biological effects in tissue are related simply to the energy absorbed, but if such an assumption be granted, as is customary, we are led to the use of an air-ionization unit of quantity of radiation for clinical purposes.

*Unit of Roentgen-Ray Dosage.*

The accepted ionization unit of dose or quantity for roentgen rays is the *roentgen* (r) which was adopted internationally in 1928 as:—

> the quantity of radiation which, when the secondary electrons are fully utilized and the wall effect of the chamber is avoided, produces in one cc. of atmospheric air at 0°C. and 76 cm. mercury pressure such a degree of conductivity that one electrostatic unit of charge is measured at saturation current.

The ionization produced by roentgen rays in air can conveniently be measured by means of either of two types of chambers:

I. *The "free-air" chamber,* in the usual form of which, a narrow beam of radiation passes through a distortionless saturation electric field between parallel-plate electrodes which are sufficiently large and separated to measure the full ionization produced by the secondary electrons from the "measured volume," which latter is unbounded by walls, but is defined geometrically by the diaphragm system of the beam and the length of the collecting electrode.

II. *The "air-wall" chamber,* in which the volume of ionized air is defined by a completely enclosing chamber, the walls of which have an effective atomic number the same as that of air. Such chambers, which are often quite small in size, are in practice completely enveloped by the beam of rays to be measured. The ionization produced in such a chamber is partly due to the secondary electrons liberated from the envelope. When the latter is made of material which is "air-equivalent" for the radiation concerned, then, as first shown theoretically by Bragg, the ionization produced in the air cavity in the chamber will be the same as if the cavity were surrounded by air. This type of chamber, which requires to be calibrated by means of a free-air chamber, has

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found extensive use for the range of rays used in medium voltage roentgen therapy.

Although the use of a free-air chamber as a primary instrument was implied in the definition of the roentgen, no specific design of chamber was actually suggested, and various workers proceeded to develop different designs of chambers in their attempts to realize the unit unambiguously. In 1931, a cooperative investigation between the national laboratories of the United States, Great Britain, Germany and France, which was undertaken for medium voltage roentgen rays, showed that the various standard free-air chambers agreed within the limits of error of observation (about 0.5 per cent). Thus the position in respect of roentgen rays could be regarded as satisfactory.

*Unit of Gamma-Ray Dosage.*

Meanwhile consideration was being given to the question of a suitable unit of gamma-ray dosage. There were objections to units based on the energy emitted by a source of radium, and as the roentgen had soon become established as a serviceable unit of roentgen-ray dosage, it was sought to investigate its suitability as a unit of gamma-ray dosage, particularly in view of the fact that combined roentgen and radium therapy is largely used in cancer treatment, and there would be obvious conveniences in employing a single unit of dosage.

It was to be anticipated that no difficulties would be encountered in the gamma-ray region in securing agreement between free-air and air-wall chambers. The results of earlier workers did not, however, support this view, the measurements with air-wall chambers appearing to be some three times as large as those with free-air chambers although the same chambers showed agreement for roentgen rays. Doubts were thus cast on the suitability of the roentgen as a unit of gamma-ray dosage; and the present work was undertaken with the object of clearing up the position if possible.

To provide a basis of comparison with the measurements of other workers, the ionization results in the present paper are expressed in terms of the conventional Sievert unit dose, that is, the quantity of gamma radiation which is received in one hour at 1 cm. from a "point source" of 1 mg. of radium with a surrounding filtration of 0.5 mm. of platinum.

It appeared that the first step in the present investigation should be to examine the present uncertainties in gamma-ray dosage measurement and to see if they could be removed by a closer specification of the experimental conditions.

## I. FREE-AIR CHAMBERS

As regards the experimental conditions of the free-air chamber, there were three main factors which appeared to need attention. The first was to ensure a specific pencil of gamma rays which, if sufficiently narrow, would not only avoid the chamber electrodes but help to minimize the extraneous scattering, both of electrons and of gamma radiation, by the environment, e.g., the boundaries of the room. This was secured by placing the radium source in a massive block of lead provided with a small hole (22 cm. long) which directed the beam of rays horizontally. The geometrical spread of the primary gamma-ray beam (including the penumbra) was about 4°. Several radium sources were employed, that used most consisting of 180 mg. of radium in a small flat platinum capsule, the front face being 0.5 mm. thick.

The other two factors were the distance of the radium from the free-air chamber and the size of the chamber, for it appeared from consideration of the long electronic ranges associated with gamma rays that both these dimensions should be large, and that the apparatus of previous workers had been on much too small a scale.

In this connection, we may recall that the definition of the roentgen requires that the ionization in the measured volume of air shall represent the total energy of the secondary electrons liberated in that volume. In the case of low and medium voltage roentgen rays, the electrons have such

short ranges that virtually the whole of their energy is absorbed within the volume of air in which they are liberated. When, however, the electrons have greater ranges, they are no longer completely arrested within the measured volume, from which, therefore, there is a leakage of energy. On

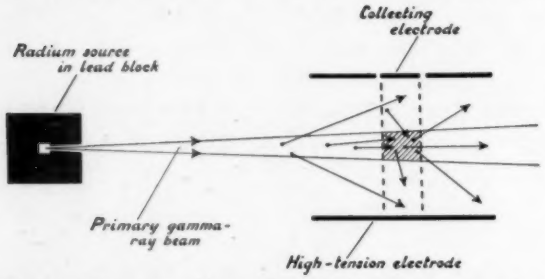


FIG. 1. Diagram of large free-air ionization chamber indicating typical electron tracks.

the other hand, some of the electrons liberated outside the volume now enter it and so contribute to the energy absorbed there. The definition of the roentgen will still be satisfied if the incoming and outgoing energies compensate; from which it follows that the measured volume must everywhere be bounded either by air of a thickness in each direction equal to the maximum range of the electrons in that direction, or alternatively, by air-wall materials of equivalent thicknesses for the particular type of radiation used.

In the case of a free-air chamber, it will be appreciated that the collecting electrode records not only the electrons in the measured volume (Fig. 1, shaded area), but also those in the "outside" volume which laterally envelops it (shown in Fig. 1 by dotted lines indicating normal planes at the edges of the collecting electrode), and which is irradiated by long-range electrons which have left the path of the gamma-ray beam obliquely on the way to the chamber. Lateral compensation in the measured volume is secured by employing electrodes big enough and sufficiently separated to provide for the full collection of these "outside" electrons, while "fore and aft" compensation is ensured if the chamber is sufficiently remote from the radium source and the far wall of the room.

*Cross-Sectional Survey of Beam.* In order to obtain a reasonably close estimate of the minimum dimensions which should be adopted for the free-air chamber, a cross-sectional survey was made within and without the periphery of the primary gamma-ray beam, to determine the distribution of direct and secondary gamma rays and accompanying electrons. The exploration was conducted by small air-wall chambers, both thin-walled and thick-walled chambers being used, in order to differentiate between ionization due to electrons and that due to gamma rays. Table I gives the number of ions per cc. per second at different points in the cross-section of the beam, 7 meters distant from the radium source. As will be seen, the secondary electrons are virtually confined within a periphery distant 2 meters from the axis of the beam.

TABLE I

DISTRIBUTION OF IONS IN THE CROSS-SECTION OF A CANALIZED GAMMA-RAY BEAM OF GEOMETRICAL SPREAD ABOUT 4° (1 IN 12)

| Radial Distance from Axis of Beam in cm. at 7 Meters from Source | Number of Ions per cc. per Second |
|---|---|
| 0 | 506 |
| 5 | 473 |
| 10 | 378 |
| 15 | 271 |
| 20 | 174 |
| 25 | 99 |
| 30* | 57 |
| 35 | 42.5 |
| 40 | 33.5 |
| 45 | 29 |
| 50 | 25 |
| 60 | 16.5 |
| 70 | 11.6 |
| 80 | 9.2 |
| 90 | 7.1 |
| 100 | 5.8 |
| 125 | 3.4 |
| 150 | 2.1 |
| 175 | 1.2 |
| 200 | 0.6 |

* Approximate geometrical periphery of direct beam.

*Design of Free-Air Chamber.* The results of the cross-sectional survey of the beam indicated that to ensure collecting sensibly all the ions produced by the secondary electrons would entail a chamber having a collecting electrode at least 4 meters high with a possible separation of not less than 4 meters between the two electrodes. Limitations of space, however, made it necessary to cut down each of these dimensions to 3 meters, though Table 1 indicates that such a chamber will collect at a distance of 7 meters from the radium source, not less than 95 per cent of the total ionization.

A photograph of the final design of chamber constructed is shown in Figure 2. The two parallel electrodes were of sheet aluminium, mounted on wooden frames and suspended vertically on horizontal wooden cross-bars by means of which it was possible to vary the electrode separation up to 3 meters. The collecting electrode consisted of 15 coplanar and separately insulated sections, each 10 cm. long (i.e., in the direction of the beam) and mounted one above another. The height of the collecting electrode could be varied between 25 cm. and 3 meters and so it was possible to vary the effective size of the ionization chamber within wide limits. The collecting electrode was surrounded by an earthed guard plate 3.5 meters high and about 1 meter long, these being also the dimensions of the high-tension electrode. The whole chamber was mounted on wheels running between guide rails so that the distance from the radium could be varied from about 1 to 7 meters. The gamma-ray beam passed horizontally and symmetrically through the chamber.

To be able to use as short a length as 1 meter for each of the electrodes and still secure a uniform field over the entire length of the collector was rendered possible by adopting a "guard-wire" system of the progressive potential type described by Taylor in connection with small free-air chambers for medium voltage roentgen-ray measurements. In the present chamber, the saturation voltage was spread over fourteen evenly spaced wires which passed right around the chamber, the plane of each loop being parallel to the electrodes, the design being carefully calculated to ensure a uniform field over the whole of the collecting electrode. In the use of the largest electrode spacing, about 20,000 volts was required to produce saturation conditions. This was controlled within about 1 volt, to avoid substantial electrostatic induction effects in the collector system. The mean reproducibility of the ionization measurements was of the order of 1 per cent.

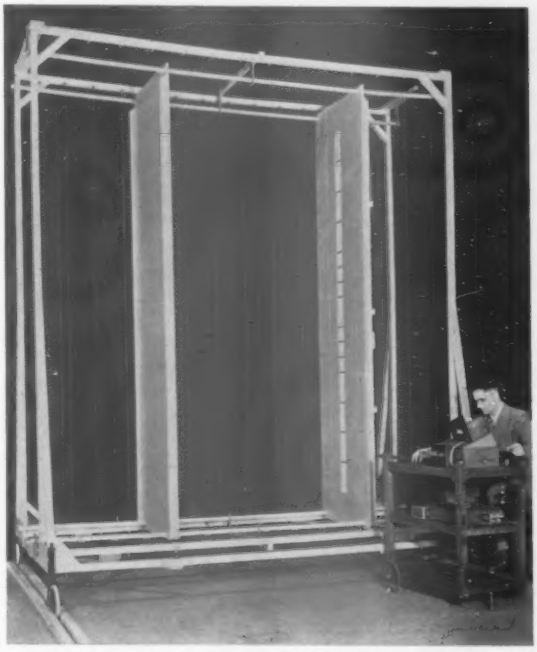

FIG. 2. Large free-air parallel-plate ionization chamber.

*The Influence of "Natural" Ionization.* The ionization produced in air by "natural" radiation, although small, was sufficient to give rise to appreciable ionization currents in a chamber as large as the present one, where the volume of air between the measuring and high-potential electrodes might be as much as 1,000 liters. For the largest electrode height and spacing used, the natural ionization was much the same as that due to the radium alone, while for the smallest height and spacing the nat-

ural ionization amounted to only about 2 per cent of the total.

Measurements of the natural ionization incidentally afforded a rough check on the uniformity of the electrostatic field in the chamber. Table II gives some typical results for various sizes of the chamber.

TABLE II

UNIFORMITY OF ELECTROSTATIC FIELD IN LARGE FREE-AIR CHAMBER

| Distance between Electrodes in cm. | Height of Collecting Electrode in cm. | Natural Ionization; Number of Ions per cc. per Second |
|---|---|---|
| 300 | 300 | 15.7 |
| 300 | 200 | 14.0 |
| 300 | 100 | 16.1 |
| 300 | 50 | 14.5 |
| 300 | 25 | 16.1 |
| 250 | 250 | 14.6 |
| 200 | 300 | 13.8 |
| 200 | 200 | 14.9 |
| 100 | 100 | 17.0 |
| 50 | 50 | 16.8 |
| 25 | 25 | 16.8 |

*Experimental Results.* The first point investigated was the influence of the effective size of the free-air chamber on the measured ionization; and, in particular, how nearly the chamber with its electrode spacing and collector height each at a maximum of 3 meters was capable of measuring the maximum possible ionization for various distances of the chamber from the radium source. In Figure 3 the measured ionization is plotted against the size of the chamber (i.e., collector height × electrode spacing) for four different radium distances, namely 125 cm. and 2, 4 and 7 meters. In each case, the ionization equivalent of the Sievert unit dose is expressed in e.s.u. per cc. of air.

It will be seen that each of the curves has very nearly attained its maximum for the largest available electrode spacing and height of collector. Although a high order of accuracy of measurement is not claimed, owing to the experimental difficulties inherent in a chamber of such large dimensions, it is significant that the ionization values at 2 meters' distance are appreciably higher than those at 4 meters, while the latter are in turn higher than those at 7 meters. This suggests that the absorption of the primary gamma rays in air is not negligible, a fact which is confirmed in the work with air-wall chambers, with which we deal later. From measurements on graphite, we estimate the absorption of the gamma rays in the air path between 2 and 4 meters to be about 0.15 e.s.u. per cc. per Sievert unit dose, while the corresponding figure for the range 2 to 7 meters is about 0.3 e.s.u. per cc. Applying these corrections to the maximum values of the curves in Figure 3 for 4 and 7 meters, we obtain values of 7.85 and 7.9 e.s.u. per cc. respectively. These are in satisfactory agreement with the maximum value of 7.8 at 2 meters.

The lower ionization values, observed at 125 cm. distance between the radium and chamber, are due to the fact that the electron compensation in the forward direction is no longer complete. The available evidence indicates that, in order to ensure complete compensation, the distance between the radium and the chamber should not be less than about 2 meters. We therefore propose to regard 2 meters of air as a basic distance to which it is desirable to refer free-air observations such as those in this paper. We deal with this point further in the next section on air-wall chambers.

To sum up, the present observations show that when the free-air chamber is of such a size that it permits the electrons to complete their paths in air, and when the chamber is at a distance from the radium source equal to the maximum forward range of the electrons, the measured ionization of a gamma-ray beam is equivalent to 7.9 e.s.u. per cc. per Sievert unit dose. As under these conditions the definition of the roentgen is satisfied, this value may be written as

*7.9 roentgens per Sievert unit dose.*

We can see now the explanation of the low values (2 to 3 r) obtained by those earlier workers who used free-air chambers in which the maximum electrode separa-

tion was no more than 20 cm. The curves in Figure 3 show that for a collector height and electrode spacing of 20 cm., the ionization values for all the radium distances used lie between 2 and 2.5 e.s.u. per cc. These values are not expressible as roentgens, since the condition of electron compensation is not fulfilled.

## II. AIR-WALL CHAMBERS

A free-air chamber with the above formidable dimensions, while serving its purpose as an ultimate standard of reference, is clearly unacceptable for routine gamma-ray observations whether of a medical or general nature. The small air-wall type of chamber would obviously be more convenient in every way, and we may now consider under what conditions it lends itself to satisfactory calibration by the large free-air standard.

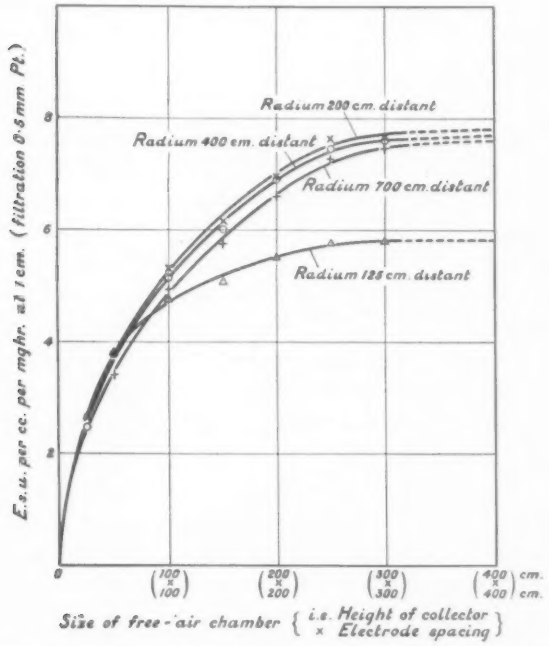
E.s.u. per cc. per mgHr. at 1 cm. (filtration 0·5 mm. Pt.)
Radium 200 cm. distant
Radium 400 cm. distant
Radium 700 cm. distant
Radium 125 cm. distant
0
2
4
6
8
(100 × 100)
(200 × 200)
(300 × 300)
(400 × 400) cm. cm.
Size of free-air chamber { i.e. Height of collector × Electrode spacing }

Fig. 3. Effect of the size of free-air chamber on the measured ionization.

*Description of Chambers.* A large variety of air-wall chambers were constructed for the purposes of the present work. They all consisted essentially of two electrodes (Fig. 4), an outer chamber wall forming the high-tension electrode and enclosing a cylindrical graphite electrode which acted as the collector. The usual experimental precautions were taken.

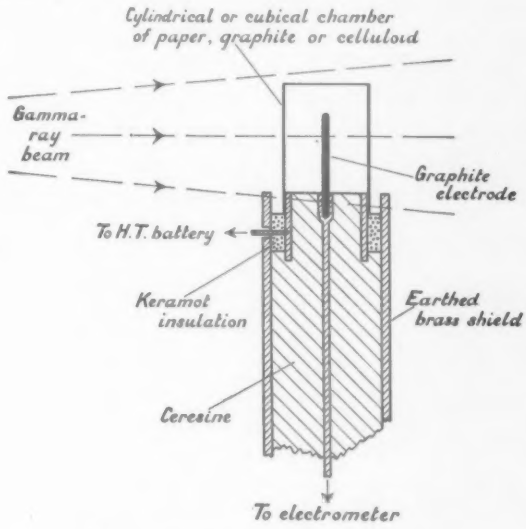


Fig. 4. Air-wall ionization chamber.

The sizes of the chambers ranged from 2 to 8,000 cc., the materials employed being graphite, graphited paper, graphited cellophane, bakelite-graphite and, on occasion, aluminium. The accuracy in measuring the volumes was estimated to be never less than ±0.5 per cent, and the mean reproducibility of the ionization readings, which were customarily made with the axis of the chamber at right angles to the beam, was of the order of 0.25 per cent.

*Experimental Results.*

(*a*) *Canalized Radiation.* In the measurements which follow, a canalized gamma-ray beam was employed as in the free-air observations.

The dependence of the ionization in an air cavity upon the thickness of the material surrounding the cavity has been established by several workers, who have shown that in the case of an air-wall chamber enveloped by a canalized beam of gamma rays, the measured ionization increases with wall thickness up to a maximum, the critical thickness of material necessary for complete electron compensation corresponding to the maximum range of the sec-

ondary electrons in the material in question. For example, the authors associated the maximum ionization with wall thicknesses of about 7 mm. of graphited paper, or 3 mm. of graphite or graphited celluloid.[1]

The individual contributions from the several walls of a cubical air-wall chamber of paper placed in the canalized beam at 50

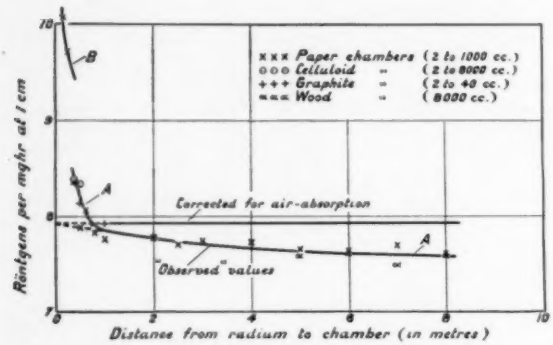
xxx Paper chambers (2 to 1000 cc.)
ooo Celluloid " (2 to 8000 cc.)
+++ Graphite " (2 to 40 cc.)
Wood " (8000 cc.)
B
A
Corrected for air-absorption
"Observed" values
A
Röntgens per mg-hr at 1 cm
Distance from radium to chamber (in metres)

FIG. 5. Ionization measurements at various distances in a canalized beam of gamma rays, using thick air-wall chambers of various sizes and materials.

cm. from the radium have also been investigated,[2] it being found that the contribution from the "near" wall was approximately the same as the total contribution from all four side walls, the rear wall contributing very little to the ionization. It was further observed that the ionization reached a maximum at approximately the same thickness for either near or side wall, suggesting that the effective maximum sidewise range of the electrons was about the same as the maximum forward range. This is in agreement with the observations with the free-air chamber referred to above, where the maximum electron ranges in the forward and sideways directions proved to be about 2 meters each in air. The maximum ionization value obtained with the cubical air-wall chamber, when all its walls were of equilibrium thickness, was 7.8 e.s.u. per cc. per Sievert unit dose.

When the walls were increased beyond the equilibrium wall thickness, there was a gradual decrease in the measured ionization, due to the absorption of the primary gamma radiation. In the case of graphite, the result of increasing the wall thickness from 3 to 6 mm. was to reduce the equivalent Sievert unit dose by about 0.045 e.s.u. per cc., while the corresponding figure for an increase from 6 to 12 mm. was about 0.035.

In Figure 5 are given the observed values at various distances along the axis of the canalized beam, using thick air-wall chambers of various materials and of sizes appropriate to the increasing cross-section of the beam. Curve *A*, which was obtained with a canalized beam from a tapered hole having a total angular spread of about 2°, reveals a somewhat rapid fall in the measured ionization values as the distance from the radium is increased up to 1 meter. In passing from 1 to 8 meters, the curve shows a gradual decrease of ionization with distance, which can be accounted for by increasing absorption of the primary gamma rays in the intervening air. The maximum electron ranges in air and graphite are about 2 meters and 3 mm. respectively, and since the absorption per millimeter of graphite over various ranges of thickness is known, the calculated absorption per meter of air would appear to be equivalent to about 0.07 and 0.05 roentgen per Sievert unit dose over the ranges 0 to 2 meters and 2 to 6 meters respectively. These values agree with the slopes of the corresponding parts of curve *A*.

Thus when we correct in Figure 5 the observed ionization values over the range 1 to 8 meters for the effect of air absorption, we obtain a horizontal straight line, indicating that over this entire range (1) the inverse-square law is obeyed (so that the amount of scattered radiation which reaches the chamber at such distances must be negligible); and (2) the dosage-rate can be calculated from a basic figure of 7.9 roentgens per mg-hr. at 1 cm.

(*b*) *Non-canalized Radiation.* We next proceeded to employ experimental conditions corresponding to those of earlier work-

[1] Kaye, G. W. C., and Binks, W. Fourth International Congress of Radiology, 1934, Vol. II, p. 124.

[2] Kaye, G. W. C., and Binks, W. Dosierung von Gammastrahlen durch Ionisationsmessung. *Strahlentherapie*, 1936, *56*, 608–620.

ers, who used unshielded radium (non-canalized radiation). In such circumstances, scattered gamma radiation from the environment was found to have a profound influence on the measured ionization, so that the roentgen equivalents of the Sievert unit dose depended on the distance from the radium at which the measurement was made. For example, in some preliminary experiments with thick air-wall chambers, the ionization values no longer obeyed the inverse-square law but rose from about 7.7 r per Sievert unit dose at short distances, to about 10.7 at the largest distance of 9 meters. The effect is clearly caused by progressively increasing scattered radiation. This explanation was verified by determining the amount of scattered radiation which reached the chamber at different distances when a solid lead cone (about 25 cm. long), of the same spread as the primary gamma-ray beam, was interposed between the radium and the chamber so that the cone just screened the chamber from the primary radiation. The results are presently turned to account.

We were next led to investigate the significance of the finite size of the ionization chamber. For the purpose, we first em-

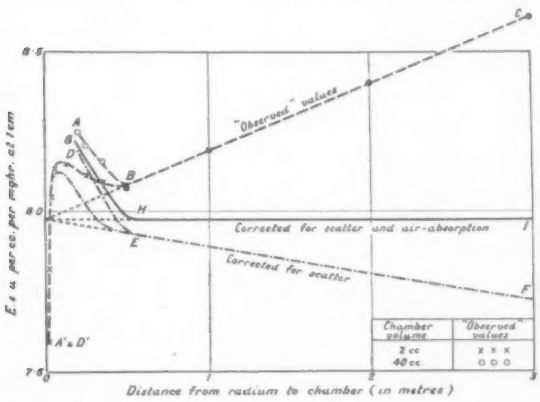


Fig. 6. Dependence of ionization in two cylindrical graphite chambers upon distance between radium and chamber, using non-canalized radiation.

ployed two cylindrical graphite chambers having very different volumes, viz., 2 cc. and 40 cc. respectively. These were used at distances of from 2 to 50 cm. and from 20 to 300 cm. respectively. It will be seen from Figure 6 that the two curves of observed values (*ABC* and *A'BC*) only coincide (*BC*) for distances greater than about 50 cm. from the radium: for shorter distances,

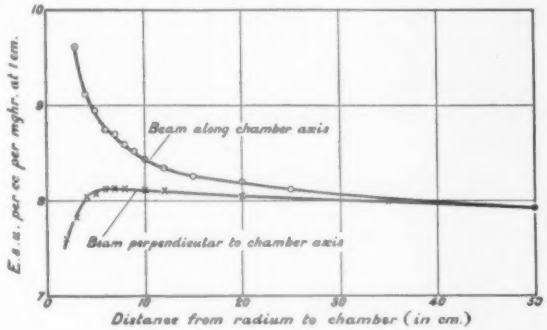


Fig. 7. Dependence of the ionization in a cylindrical graphite chamber on whether the radium beam is along or perpendicular to the chamber axis, using non-canalized radiation.

the larger chamber gives the higher values. The explanation would appear to be that, since the electrons which produce the ionization in the air-cavity come almost entirely from the near half of the chamber, the larger the chamber, the nearer is the effective center to the radium. The divergence between the effective and the geometrical center is sufficient to be appreciable at short distances, and accounts for the lack of agreement between the two chambers in Figure 6.

To test the explanation further, we took the smaller of the two cylindrical chambers, in which the length was slightly greater than the diameter, and measured the ionization at various distances from the radium, first with the radium along the axis of the cylinder and then at right angles to the axis. The flat end of the chamber was farther than the cylindrical wall from the geometrical center, and we found, as we had anticipated, that the ionization values with the radiation directed through the flat end were always higher than those taken through the cylindrical wall (Fig. 7), the divergence being the greater for the shorter radium-chamber distances. The point was further confirmed by employing

a cubical paper chamber of about 4 cc. volume, for which the effective centers as viewed in the two directions should be equidistant from the geometrical center of the chamber. In this case, the ionization was found to be the same in the two positions for the same radium-chamber distance.

These results have a bearing on Figures 6 and 7, the shapes of the curves suggesting that at the shortest distances the observations are vitiated by the finite sizes of the measuring chambers. That this is the case will be seen from Figure 6 to which we may now apply in turn corrections for scatter, as determined above, and for air absorption. The correction for scatter gives us curves *DEF* and *D'EF*, while a further correction for air absorption gives us curve *GHI*, of which the portion *HI* is a horizontal straight line, clearly obeying the inverse square law. At distances less than 50 cm. there is a departure from the law, the departure being greater for the larger chamber.

In order, therefore, to obtain the dosage rate at the conventional 1 cm. distance, it will be best to extrapolate from the greater distances. For the purpose, any one of the three curves in Figure 6, viz. *CB*, *FE*, or *IH* will suffice, and as will be seen, all three afford the same result, which is close to

*8.0 e.s.u. per cc. per Sievert unit dose.*

In passing, we may note that most previous workers have restricted their ionization measurements to small radium distances—up to about 20 cm., and have found that for the larger of these distances, the inverse-square law appeared to hold. From this they have been led to conclude that the finite sizes of their chambers do not matter at such distances. As will be seen, however, from Figure 6, the position, as illustrated by the observations with the 2 cc. chamber, is that while the observed ionization values do roughly obey the inverse-square law for distances between about 6 and 20 cm. (the upper part of curve *A'B*), the numerical values of the Sievert unit dose over this range are actually too high by about 0.2 roentgen.

*Discussion of Results with Free-Air and Air-Wall Chambers.*

It will be seen that in the case of air-wall chambers with walls of equilibrium thickness, there is satisfactory agreement between the observed ionization values at distances between 1 and 3 meters from the radium in a canalized beam (Fig. 5), and the corresponding values for non-canalized radiation after corrections have been applied for scattering (Fig. 6; curve *EF*), the value of 8.0 e.s.u. per cc. per Sievert unit dose for non-canalized radiation agreeing closely with the value of 7.9 for canalized radiation. Since these two values were both obtained with equilibrium air-wall chambers under conditions in which the inverse-square law is obeyed, they may be correctly translated as 8.0 and 7.9 roentgens per Sievert unit dose. In view of the greater consistency of the results for non-canalized radiation, we are led to adopt the higher value, that is

*8.0 roentgens per Sievert unit dose.*

The corresponding result with the large free-air chamber, was *7.9 roentgens* at a distance of 2 meters of air from the radium, which distance corresponds to the equilibrium thickness of the walls of an air-wall chamber. Thus under these comparable conditions, the agreement between the values from the two types of chambers can be regarded as sufficiently satisfactory not only to warrant the use of equilibrium air-wall chambers as gamma-ray dosemeters, but also to establish the suitability of the roentgen as a unit of quantity of gamma radiation.

*Comparison with the Results of Other Workers.*

In attempting to contrast the results of various workers who have used air-wall chambers, it was not always possible to avoid uncertainty in reducing the different experimental conditions to those required

by the Sievert unit dose. Among the difficulties are:

(1) The absorption of the radiation in the radium salt, in the case of the larger radium sources.
(2) The reduction of containers and filters of various metals to the standard filtration of 0.5 mm. Pt.
(3) The use of materials which are not truly "air-wall."
(4) The use of chamber-wall thicknesses other than the "equilibrium" thickness.
(5) The influence of undue extraneous scattered radiation.
(6) The effect of the finite sizes of the radium sources and chambers.

In view of the above, it is perhaps not surprising that there are discrepancies in the published roentgen equivalents of the Sievert unit dose. In Table III, we have attempted to reduce to a comparable basis, the results of the more recent workers, who have in general used non-canalized radiation and thick-walled chambers at radium distances less than 25 cm. In such circumstances, item (5) can therefore probably be ruled out and as item (6) is usually unappraisable, the items utilized in the successive columns of Table III are therefore limited to (1), (2), (3) and (4).

*Thin Air-Wall Chambers.*

Although we may perhaps regard the major problem as having been solved, we should like to refer for a moment to certain measurements which we have conducted with air-wall chambers having very thin walls. The results of such measurements, first of all for a canalized gamma-ray beam, are exemplified in Figure 8 for various radium distances. The shapes of the curves

TABLE III

MEASUREMENTS WITH NON-CANALIZED GAMMA RADIATION AND THICK AIR-WALLED CHAMBERS
(Radium distances less than 25 cm.)

| Authors | e.s.u. per cc. per mg-hr. at 1 cm. | | | | |
|---|---|---|---|---|---|
| | "Observed" | Corrected for absorption in radium salt | Corrected to 0.5 mm. Pt filtration | Corrected to air-wall material | Corrected to "equilibrium" wall thickness |
| Mayneord and Roberts[1] 1934 | 8.3 | 8.3 | 8.3 | 8.3 | 8.3 |
| Sievert[2] 1934 | 7·55 | 7·55 | 7·7 | 7·7 | 7·7 |
| Murdoch and Stahel[3] 1935; 1936 | 8.1 | 8.1 | 8.1 | 7·5 | 7.6 |
| Friedrich and Schulze[4] 1935 | 7.8 | 7.8 | 7.8 | 7.8 | 7.8 |
| Grimmett and Read[5] 1935 | 9.15 | 9.05 | 9.2 | 8.7 | 8.8 |
| Glasser and Rovner[6] 1936 | 8.8 | 8.8 | 8.8 | 8.8 | 8.8 |
| Kaye and Binks[7] 1936 | 7.8 | 7.8 | 7.8 | 7.8 | 7.8 |
| Smereker[8] 1937 | 7·75 | 7·9 | 7·9 | 7·4 | 7·5 |
| Kaye and Binks 1937 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 |
| Mean | — | — | — | — | 8.0 |

[1] Mayneord, W. V., and Roberts, J. E. Ionisation produced in air by x rays and gamma rays. *Brit. J. Radiol.*, 1934, *7*, 158–175.
[2] Sievert, R. M. Ueber die Anwendung der Kondensatorkammer für sowohl Röntgen-wie γ-Strahlenmessungen. *Acta radiol.*, 1934, *15*, 193–201.
[3] Murdoch, J., and Stahel, E. Ueber die Dosierung der Gammastrahlen in r-Einheiten. *Strahlentherapie*, 1935, *53*, 102–118. Murdoch, J., Stahel, E., and Simons, S. Ueber die Dosismessung in der Radiumtherapie. *Strahlentherapie*, 1936, *57*, 87–93.
[4] Friedrich, W., and Schulze, R. Neubestimmung der r-Einheit für Gammastrahlen. *Strahlentherapie*, 1935, *45*, 553–569.
[5] Grimmett, L. G., and Read, J. Measurement in röntgens of distribution in water of intensity of radiation from 3 gm. and 4.9 gm. radium unit. *Brit. J. Radiol.*, 1935, *8*, 702–713.
[6] Glasser, O., and Rovner, L. Dosimetry in radiation therapy; gamma-ray measurements in roentgens. Am. J. Roentgenol. & Rad. Therapy, 1936, *36*, 94–104.
[7] Kaye, G. W. C., and Binks, W. Dosierung von Gammastrahlen durch Ionisationsmessung. *Strahlentherapie*, 1936, *56*, 608–620.
[8] Smereker, H. Untersuchung der Strahlenintensität in der Nähe radioaktiver Präparate mit dünnwandigen Ionisationskammern *Strahlentherapie*, 1937, *58*, 267–285.

may be explained as follows. At short distances from the radium, part of the ionization is contributed by electrons which reach the chamber from the platinum filter and the lead walls of the aperture in the

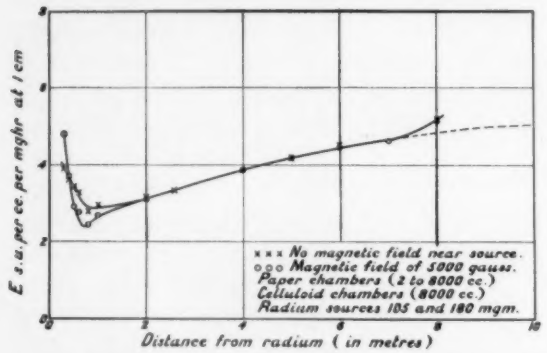
E.s.u. per cc. per mghr. at 1 cm.
Distance from radium (in metres)
xxx No magnetic field near source.
ooo Magnetic field of 5000 gauss.
Paper chambers (2 to 8000 cc.)
Celluloid chambers (8000 cc.)
Radium sources 185 and 180 mgm.

Fig. 8. Effect on measured ionization of varying the distance between radium source and thin air-wall chambers of various sizes and materials, using a canalized gamma-ray beam.

canalizing block. This was confirmed by applying a strong magnetic field near the aperture, when in general the resulting deviation of the electrons produced, as will be seen, a noticeable reduction in the measured ionization. As the radium distance is increased, fewer of the electrons from the platinum and lead reach the chamber, but in their place we have more and more electrons from the air, so producing a steady rise in the ionization over a distance of from 2 to 7 meters.

The experiment was now repeated with the same gamma-ray beam, but this time using the large free-air chamber, the separation of the electrodes being adjusted until they were situated just on the periphery of the geometrical beam. It was then found that the part of the curve in Figure 8 between 2 and 7 meters was reproduced quantitatively, and as we may take it that, under such conditions, the free-air chamber can only measure the energy absorbed from those electrons actually within the primary beam, we conclude that very thin air-wall chambers also afford a means of measuring the energy absorbed from the electrons within the gamma-ray beam itself.

Figure 9 deals with similar measurements to those in Figure 8, again using very thin-walled chambers but this time with non-canalized radiation. The curves reflect the complexity of the conditions, for we are now dealing not only with scattered electrons from the platinum, lead, air and the general environment, but with considerable extraneous scattered gamma radiation. Little significance should be attached to the numerical values recorded in Figure 9, since they merely illustrate a particular set of experimental conditions, and are scarcely likely to be reproduced in other circumstances. One's main comment is that the ionization values are always larger than those obtained with thick-wall chambers under similar conditions.

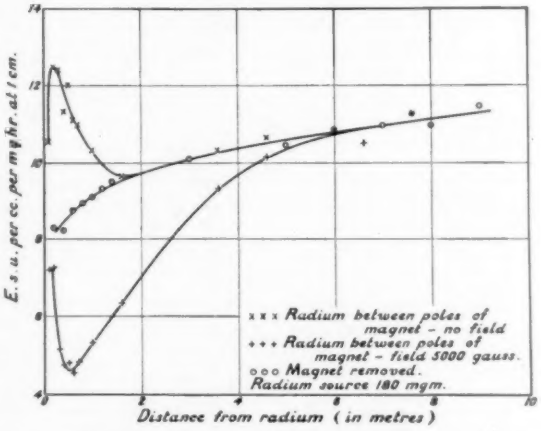
E.s.u. per cc. per mghr. at 1 cm.
Distance from radium (in metres)
xxx Radium between poles of magnet – no field
+++ Radium between poles of magnet – field 5000 gauss.
ooo Magnet removed.
Radium source 180 mgm.

Fig. 9. Effect on measured ionization of varying the distance between radium source and thin air-wall paper chambers of varying sizes, using a non-canalized gamma-ray beam.

*Clinical Bearing of the Results.*

It will be appreciated that a thick air-wall chamber has its clinical limitations, in that there are locations where it does not give a true measure of a dose in tissue. For example, in the case of a radium needle buried in tissue, a chamber having walls 3 mm. thick can only be used to measure doses in tissue at distances of 3 mm. or more from the needle. If we wish to ascertain the dose received by a cell nearer to or in actual contact with the needle, we can most conveniently determine the ener-

gy absorbed from the electrons passing through the cell by means of a very thin air-wall chamber. In point of fact, such a chamber is of universal application, since it will equally well measure the electronic energy absorbed at any point, whether in free air, or on the surface of tissue, or within it. Such measurements should however be stated in e.s.u. per cc. and not in roentgens, since the thin air-wall chamber does not satisfy the definition of the roentgen.

On balance, however, it is realized that, from a practical point of view, the fragility of thin-walled chambers, together with their susceptibility to extraneous scattered beta radiation, are such as to render them unsuitable for routine medical purposes. Thick-walled chambers are to be preferred, for although they are inadequate in certain locations, they can in most circumstances be relied upon to measure dosage correctly in roentgens.

*Revised Definition of the Roentgen.*

In order to clarify the use of the roentgen in the light of the knowledge gained in gamma-ray dosage measurements, we suggest, in view of the foregoing, that the present definition could advantageously be modified on some such lines as the following, the wording of which is designed to deal both with gamma rays and roentgen rays of all wave lengths:

The *roentgen* shall be that quantity or "dose" of x or gamma radiation, whether direct or scattered, which, received at any point, would liberate under saturation conditions an ionic charge (of either sign) of one electrostatic unit per cubic centimeter in an indefinitely small volume of dry air at 0°C. and 76 cm. mercury pressure* situated at that point, the air being bounded by an envelope† of air or air-equivalent material** of thickness equal to the maximum range of the secondary particles liberated by the radiation from the envelope and contributing to the ionization.

With regard to the above definition, it is appreciated that in certain clinical circumstances a dose measured in roentgens may differ from the physical concept of quantity of radiation as set out at the beginning of this paper, but despite such occasional limitations, it would appear that the roentgen, as so defined, forms a convenient practical unit which is sufficiently accurate for present-day medical requirements.

* More precisely, at "standard atmospheric pressure."

† It is assumed that the introduction of the envelope does not disturb the quantity of radiation reaching the point.

** "Air-equivalent" material is understood to have the same properties as air in regard to the absorption and scattering of the particular radiation employed.

# SOME PROBLEMS OF GAMMA-RAY MEASUREMENT IN RADIOLOGY*

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ABSTRACT

The calibration of thimble chambers for the measurement of gamma rays in roentgens is discussed. The correction that should be applied because the materials used in the walls of these chambers are not generally "air equivalent" is described and data are given for evaluating it under various conditions. When thus corrected the recently published measurements of the intensity of gamma rays filtered through 0.5 mm. of platinum from 1 mg. of radium in equilibrium with its products at 1 cm. distance agree with a mean deviation of 2 per cent from the value 8.4 roentgens per hour.

The design of thimble chambers and phantoms for gamma-ray measurement is discussed.

Present uncertainties about the meaning of the roentgen under practical conditions have hindered the use of these units in gamma-ray therapy. Certain conventions are proposed to remove these uncertainties.

The density of ionization per roentgen in any material varies considerably with the nature of adjacent materials and is probably an important factor in determining the biological effects of gamma-ray exposure of the skin. The approximate measurement of the variation in the density of ionization per roentgen in a solid material is described.

## CALIBRATION OF THIMBLE IONIZATION CHAMBERS

THE use of the roentgen for gamma-ray measurement in radiology is prompted by the desire to have a common unit for use in both x-ray and radium therapy. The greatest objection to its use with gamma rays has been technical difficulties but since many of these difficulties, which occur also in measuring extra hard roentgen rays, must be overcome in any case the objection will probably disappear.

The International Committee on X-Ray Standards has defined that "the roentgen shall be the quantity of x-radiation which, when the secondary electrons are fully utilized and the wall effect of the chamber is avoided, produces in one cubic centimeter of atmospheric air at 0°C. and 76 cm. mercury pressure, such a degree of conductivity that one electrostatic unit of charge is measured at saturation current."

To avoid the wall effects mentioned in this definition the dimensions of the chamber must exceed twice the maximum range of the secondary beta rays produced by the radiation. This is almost impracticable for gamma rays because their secondary beta rays have ranges up to a few meters, and it may be necessary to modify the design of the standard chamber for very hard radiation. Until these difficulties have been overcome and a satisfactory standard has been established it is possible to calibrate practical instruments by indirect methods in units that are approximately equal to the roentgen that would be standardized by a literal application of the above definition. Thus, a suitable thimble chamber can be calibrated approximately in roentgens by theoretical considerations using the known properties of the gamma rays and secondary beta rays. There has been some hesitation to accept indirect calibrations because measurements based on them of the intensity of gamma rays under comparable conditions have disagreed widely and led to the opinion that they are unreliable. The large discrepancies between the earliest of these measurements may be explained by instrumental sources of error that were not well understood at the time the measurements were made. The discrepancies between the more recent measurements result chiefly from differences in the choice of material for the walls of the thimble chamber. When these measurements are corrected for the effects of the material in

* Presented at the Fifth International Congress of Radiology, Chicago, Ill., Sept. 13–17, 1937.

the chamber wall, by methods that are briefly described below, they agree with a mean deviation of 2 per cent. The method therefore is sufficiently precise for most practical purposes and it is probably capable when the wall corrections are applied of an accuracy in roentgens of 2 per cent.

The results of some recent measurements of the intensity in roentgens per hour at 1 cm. distance from 1 mg. of radium in equilibrium with its disintegration products and enclosed in platinum with an effective thickness of 0.5 mm. are quoted in Table 1. The second column gives the values published by the respective authors. The fourth column is the corrections that should be applied for the wall effects. The fifth column is the values obtained after the correction by dividing by the factors in the fourth column. The improvement in precision is evident. Some of these measurements were made with chambers that did not fully satisfy the conditions that were assumed in deriving the correction factors, and better agreement is to be expected with chambers to which the corrections are better applicable.

The wall correction is derived from the accepted theories of gamma-ray and beta-ray absorption by a method described in a previous paper.[1] A brief summary of its derivation will be sufficient in this discussion which is concerned chiefly with the application of the method.

It follows almost directly from the definition of the roentgen standard that 1 roentgen produces, near a point that is situated not less than the maximum range of the secondary beta rays from the boundaries of a very large volume of air that is uniformly irradiated, an ionization* that yields 1 e.s.u. per cc. if measured under saturation conditions at standard temperature and pressure. (It is assumed that the absorption in the air is suitably corrected.) The air surrounding the "test volume" in which the ionization is imagined to be measured may be regarded as an "air wall" of a thimble chamber. If the test volume is quite small, the ionization within it is produced almost entirely by beta rays that originated in the air wall. If now the air wall is replaced by a solid wall of convenient material the ionization density in the test volume is altered according to the change in the number of beta rays from the wall crossing the test volume. If the ionization density is increased in the ratio $B$ the

TABLE I

INTENSITY IN ROENTGENS PER HOUR AT 1 CM. FROM 1 MG. RADIUM IN EQUILIBRIUM THROUGH 0.5 MM. PT

| Authority | Measured Intensity | Chamber Wall | $B$ | Corrected Intensity |
|---|---|---|---|---|
| Friedrich and Schulze* | 7.8 | Carbon | 0.977 | 8.0 |
| Murdoch and Stahel† | 8.05 | Ebonite | 0.959 | 8.4 |
| " " " | 8.29 | Paper | 0.968 | 8.6 |
| Mayneord and Roberts** | 8.3 | Carbon | 0.977 | 8.5 |
| Sievert‡ | 7.7 | Celluloid | 0.968 | 7.95 |
| Grimmett and Read*** | 9.4 | Elektron | 1.074 | 8.65 |
| | | Mean value..... | | 8.35 |

* Friedrich, W., and Schulze, R. Neubestimmung der r-Einheit für Gammastrahlen. *Strahlentherapie*, 1935, *54*, 553–569.

† Murdoch, J., and Stahel, E. Ueber die Dosierung der Gammastrahlen in r-Einheiten. *Strahlentherapie*, 1935, *53*, 102–118.

** Mayneord, W. V., and Roberts, J. E. Ionisation produced in air by x rays and gamma rays. *Brit. J. Radiol.*, 1934, *7*, 158–175.

‡ Sievert, R. M. Ueber die Anwendung der Kondensatorkammer für sowohl Röntgen-wie-γ-Strahlenmessungen. *Acta radiol.*, 1934, *15*, 193–201.

*** Grimmett, L. G., and Read, J. Measurement in röntgens of distribution in water of intensity of radiation from 3 gm. and 4.9 gm. radium unit. *Brit. J. Radiol.*, 1935, *8*, 702–713.

* The number of roentgens thus described is a measure of the *total* radiation including that which is scattered in the air volume itself. When radiation from the source only is considered, only the ionization produced by the photo and recoil electrons excited by the direct rays from the source is to be included.

correction factor for this chamber is $1/B$. The number of beta rays crossing the test volume depends on the number of beta rays per unit volume generated in the wall and the rate of loss of energy per unit path length of the beta rays in the wall material. It is proved that their number does not depend on the nuclear scattering in the wall material if the wall is composed of the same material throughout on all sides, and therefore nuclear scattering may be disregarded. If the radiation is quite hard and the wall consists of materials of low atomic number, a condition that is easily satisfied for gamma rays, the photoelectric production of beta rays may be ignored, and the number and energy of the beta rays produced is given by the theory of Klein and Nishina.[2] The rate of loss of energy of the beta rays in penetrating the wall is given by Bloch's theory[3] which is shown to agree closely with experimental data published by several authors. An expression is derived from these theories for the number and energy of the beta rays that enter the test volume and the ionization density is determined. It is shown by this method that

$$B=1+F(Z)\mathcal{J}/L+(F(Z))^2K/L+\cdots. \quad (1)$$

with

$$F(Z)=2\log_e Z-3.948$$

in which $Z$ is the atomic number of the wall material. If the material contains more than one element, $2\log_e Z$ should be replaced by $2\sum N_z Z\log_e Z/\sum N_z Z$ wherein $N_z$ is the relative number of atoms of atomic number $Z$. Values of $F(Z)$ and $(F(Z))^2$ for some materials are given in Table II. $\mathcal{J}$, $K$ and $L$ are functions of the energy of the gamma rays. They are plotted as $\mathcal{J}_k$, $K_k$ and $L_k$ in Figure 1 for monochromatic gamma rays of energy $h\nu$ as functions of $k=h\nu/mc^2$. ($mc^2$ is the rest mass energy of an electron and is equal to 510,000 electron volts.)

If the radiation consists of a number of monochromatic lines of relative intensities $a_k$ expressed in quanta per second per square centimeter,

$$\mathcal{J}=\Sigma a_k\mathcal{J}_k/\Sigma a_k, \qquad K=\Sigma a_k K_k/\Sigma a_k,$$
$$L=\Sigma a_k L_k/\Sigma a_k\cdots. \quad (2)$$

Similarly for a continuous spectrum with $db$ quanta per second per square centimeter with energies between $k$ and $k+dk$,

$$\mathcal{J}=\int\frac{db}{dk}\mathcal{J}_k dk/\int db, \quad K=\int\frac{db}{dk}K_k dk/\int db,$$
$$L=\int\frac{db}{dk}L_k dk/\int db\cdots. \quad (3)$$

Graphical integration of these terms for gamma rays from radium in equilibrium with its distintegration products and enclosed in a platinum tube of 0.5 mm. wall thickness, with the effects of scattered and secondary gamma rays from the wall included, gave the following ratios:

$$\mathcal{J}/L=.0644, \qquad K/L=.0039$$

These values are sufficiently accurate for most practical purposes with any filtration not less than 0.5 mm. platinum or the equivalent. For example, the greatest increase in filtration likely to be used in practice would alter the value of $B$ for an aluminium chamber by less than 0.3 per cent.

TABLE II

| Material | $Z$ | $F(Z)=2\log Z-3.948$ | $(F(Z))^2=(2\log Z-3.948)^2$ |
|---|---|---|---|
| H | 1 | −3.948 | 15.59 |
| Li | 3 | −1.752 | 3.07 |
| Be | 4 | −1.176 | 1.38 |
| B | 5 | −0.730 | 0.53 |
| C | 6 | −0.364 | 0.13 |
| N | 7 | −0.052 | 0.00 |
| O | 8 | 0.226 | 0.05 |
| F | 9 | 0.446 | 0.20 |
| Na | 11 | 0.848 | 0.72 |
| Mg | 12 | 1.022 | 1.04 |
| Al | 13 | 1.182 | 1.40 |
| S | 16 | 2.786 | 7.73 |
| Air | (7.2) | 0 | 0 |
| (Water | (5.3) | −0.609 | 0.37) |
| Bakelite | | −0.657 | 0.43 |
| Amber | | −1.100 | 1.21 |
| Cellulose | | −0.506 | 0.26 |
| Elektron | | 1.088 | 1.18 |
| Protein materials | | −0.624 | 0.387 |
| Skin, muscle | | −0.61 | 0.38 |
| Wood | | −0.54 | 0.30 |
| Paraffin wax | | −1.260 | 1.59 |

Values of $B$ for the gamma rays from radium in equilibrium through a filtration of 0.5 mm. of platinum for a number of wall materials are given in Table III.

TABLE III

VALUES OF B FOR GAMMA RAYS AS SPECIFIED IN TEXT

| Material | $B$ |
|---|---|
| Sulphur | 1.209 |
| Aluminium | 1.081 |
| Elektron | 1.075 |
| Carbon | 0.977 |
| Cellulose materials | 0.968 |
| Wood | 0.966 |
| Protein materials | 0.962 |
| Pure bakelite | 0.960 |
| Commercial bakelite | 0.962–0.966 |
| Amber | 0.934 |
| Paraffin wax | 0.925 |

Wall corrections derived by this method are applicable also in the measurement of extra hard roentgen rays generated by very high potential roentgen tubes with sufficient filtration to eliminate nearly all of the radiation that is softer than 0.1Å. It is sufficiently accurate for most purposes to use values of $\mathcal{J}$, $K$ and $L$ from Figure 1 that correspond to an estimated mid point in the spectrum instead of carrying out the integration of (3).

This wall correction is applicable only if the following conditions are satisfied. (1) The chamber walls are of the same material on all sides except at the insulating bushing and are thick enough to prevent the fastest beta rays from penetrating them. The insulating bushing through which the central electrode wire enters the chamber is so small that the difference in atomic composition between it and the rest of the wall produces negligible error. (2) The collecting electrode is composed of the same material as the wall, or is a fine wire having a surface area that is very small compared with the walls. (3) The atomic numbers of the elements in the wall are so small, and the radiation is so hard that the production of beta rays by the photoelectric effect may be ignored. (4) Absorption and scattering in the walls is small and correction for it is applied (see below). (5) The air space is so small that the production of beta rays in the air may be ignored.

In appraising the accuracy of $B$ errors caused by the theoretical and mathematical approximations that were made in deriving the equations and in integrating to obtain the curves of Figure 1 may be considered to be quite small since $\mathcal{J}$, $K$ and $L$ appear only in the relatively small second, third and later terms of the expansion of $B$ in equation (1). The more important source of error arises from the difficulty of achieving the five conditions mentioned above, particularly the fourth condition, and in determining the correction for absorption and scattering of the gamma rays in the chamber wall.

The correction for absorption and scattering of the gamma rays in the wall is most simply determined experimentally by observing the decrease in ionization caused by increasing the wall thickness by the addition of shells of the same material, and in extrapolating the curve showing ionization current as a function of total wall thickness to zero wall thickness. It is important that the shells be designed to increase the wall thickness uniformly in all directions and for this reason it is recommended that the chamber be spherical with equal wall thickness along all radia and that the shells be pairs of hemispherical cups that fit snugly over it. The reason for this precaution is readily appreciated; the scattered radiation comes from all parts of the wall and therefore the assumption that the absorption and scattering correction is approximately proportional to the wall thickness is justified only if the wall thickness is altered by the same ratio on all sides.

For spherical chambers made of convenient materials of organic composition and free from heavy elements, used with gamma rays from radium in equilibrium with its products and filtered by 0.5 mm. platinum the absorption and scattering correction is approximately $t\rho \times (-2.6\%)$, where $t$ is the radial wall thickness in centimeters and $\rho$ the specific gravity. It may be no-

ticed that the coefficient 0.026 is considerably smaller than the true absorption coefficient owing to the scattering.

Calibration of thimble chambers for extra hard radiation is sometimes attempted by extrapolation from the calibration for moderately hard radiation. Calibration by that method is unreliable for it has been found in a few typical cases that the combined effects of the absorption and the yield of beta rays from the walls cause a flattening of the calibration curve in the region of moderately hard quality that is misleading in attempting to extrapolate the curve to extra hard radiation.

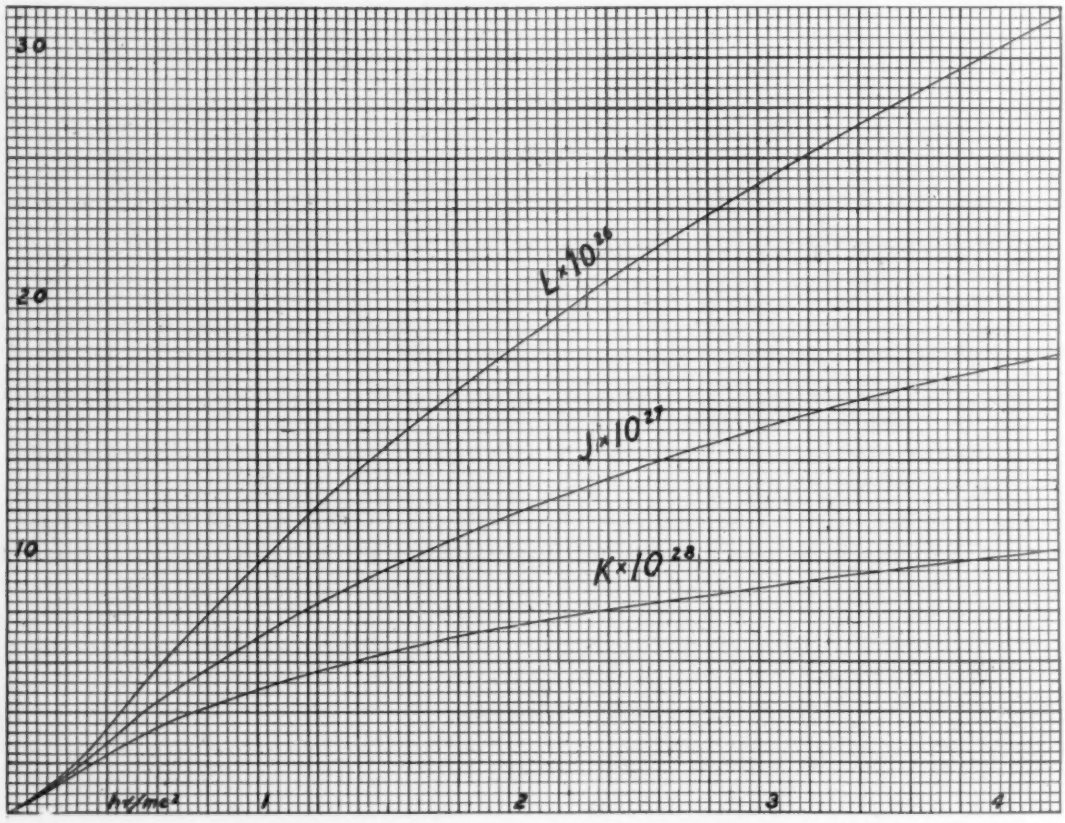


FIG. 1. Values of $K_\epsilon$, $\mathcal{J}_\epsilon$ and $L_\epsilon$ plotted as functions of $\epsilon = h\nu/mc^2$.

## DIFFICULTIES OF PRACTICAL MEASUREMENT

The distances between the radium containers and the tissue that is treated are usually quite small and it is sometimes necessary in practice, therefore, to use a very small chamber in which the walls are thinner than the ranges of the beta rays. Beta rays from the outside penetrate the thin walls and contribute to the ionization in the enclosed air and hence the surrounding material is a significant part of the walls. One method of overcoming this source of error in using a chamber with a thin wall is to make the wall of material that is similar in properties to the material in which the chamber will be embedded during measurements. For example, a small bakelite chamber with a very thin wall might be used in a bakelite phantom. This phantom might be made of blocks and sheets of bakelite placed around the chamber. The region of the phantom close to the chamber is virtually a part of the chamber wall contributing beta rays to the air space, but since it is of

the same material no error will result from this cause. When the chamber is being calibrated by comparison with the standard it should be placed in a block of bakelite sufficiently thick to exclude external beta rays. If, however, this chamber is calibrated by calculation from its dimensions the value of $B$ for bakelite is used of course in determining the wall correction.

The important requirement in choosing materials for the wall of the chamber and for the phantom is that $F(Z)$ differ very little in the two materials. Water ($F(Z) = -0.16$), paraffin wax ($-1.26$), and dense hard wood ($-0.54$) have suitable densities and gamma-ray absorption constants for use as phantom materials, and accordingly a thin-walled bakelite chamber ($-0.66$ for pure bakelite, to $-0.54$ for bakelite containing considerable paper or cloth binder) may be used in a water or hardwood phantom, and an amber chamber ($-1.10$) in a paraffin wax phantom.

The following design of phantom is suggested (in which are incorporated some improvements for convenience on a phantom recently constructed in this laboratory). The ionization chamber consists of a bakelite shell 2 mm. thick surrounding a spherical air volume of about 0.1 cc. painted inside with a very thin layer of colloidal graphite (sold under the trade name "Aquadag"). Connection to the inside graphite conducting layer is made by a fine aluminium wire. The central electrode is a fine aluminium wire protruding through a small sealing wax bushing and led through a hollow bakelite tube to the grid of the electrometer valve.* The wire is embedded in sealing wax throughout the length of the hollow tube, and the grid terminal and biasing resistor ($10^{10}$ to $10^{12}$ ohms) is also embedded in sealing wax to exclude air pockets that would permit spurious ionization currents. The chamber and connecting tube fit snugly in recesses in an oak block 10 cm. to 20 cm. thick, underneath, and an oak board, 8 mm. thick, above. The radium needles are fastened to a strip of bakelite about 4 mm. thick in the desired arrangement by adhesive tape. The required depth is obtained by placing thin oak boards or sheets of paper between the bakelite slab and the board that is directly over the chamber. A piece of millimeter graph paper pasted on the bakelite slab and vertical strips of wood fastened to the corners of the bottom board are convenient for locating the lateral position of the chamber with respect to the needles.

Skin exposure is frequently of particular interest and the data obtained with a phantom are only applicable in determining the quantity of radiation at the skin surface for treatments in which the skin is covered to a depth of at least 1 cm. under the gamma-ray source with a material that has about the same density and absorption constant for the radiation as the skin and underlying tissue. While it is not always possible to make measurements under the conditions of treatment, it is frequently possible to arrange the conditions of treatment so that they can be reproduced in a phantom for satisfactory measurements. For example, in techniques in which the radium is supported 1 cm. or more above the skin the material used to support the radium preparations should be the same as used in the phantom. In using a radium bomb a slab 1 cm. thick of the material used in the phantom should be placed between the metal parts of the bomb and the skin.

Similarly in using extra hard roentgen rays a slab of the phantom material should be placed over the skin. It is suggested that this slab be permanently fastened to the base of the treatment cone and a small thimble ionization chamber be placed in a slot in the slab. If the design of the chamber and slab conforms to the requirements that have been discussed the skin exposure can be read directly with the ionization chamber corrected for the slight difference in the distances of the chamber and skin from the source of radiation. The important source of error in doing this is the variation in intensity in the slab and body tissue owing to scattering. The variation is

* General Electric Co. FP54 or similar type.

most rapid near the surface of the slab that is closest to the source of the roentgen rays. Hence the error can be reduced considerably if the slab is quite thick, e.g. 5 cm., and the chamber is as close as possible to the skin surface. The loss in intensity in penetrating the thick slab is not great enough to be very objectionable with extra hard roentgen rays. Since it is desirable to have the chamber as close as possible to the skin its wall thickness next the skin may be quite thin if the values of F(Z) for the wall material and the slab material do not differ greatly from the value for skin: −0.6. Paper base commercial bakelite is suggested for the slab and the chamber wall.

Another method of avoiding error in using a thin-walled chamber is to calibrate the chamber (by comparison with the standard chamber) under the same conditions that will exist when it is used for measurement, i.e., embedded in the same material and exposed to the same quality of radiation. Thus a chamber that is to be used for measurements in the natural body cavities should be calibrated with radiation of the same quality while it is surrounded by a piece of meat thick enough to exclude secondary beta rays from without. A chamber made of hard aluminium or elektron alloy in the shape and size of a radium needle might even be used for interstitial measurements during treatment if calibrated under similar conditions.

By the above methods it is feasible to measure gamma rays in roentgens except within about a centimeter distance of the radium container. Sufficient thickness of the material in which the thin-walled chamber has been calibrated must intervene to exclude secondary beta rays from the radium container. It is probably not a serious disadvantage to be unable to make measurements within a centimeter of the source because it would be very difficult to correlate the biological effects of the treatment with the dose in this region where the intensity varies so rapidly.

There is a possible error owing to the presence of the chamber air space, usually less than 1 per cent if the space has a volume less than 0.3 cc. and the distance between radium and chamber is not less than 1 cm.

## THE MEANING OF THE ROENTGEN UNDER VARIOUS PRACTICAL CONDITIONS

Some uncertainties remain in the meaning of the roentgen when this unit is used in describing radiation under conditions encountered in therapy that differ from the conditions specified in the definition of the standard. Difficulty with these uncertainties has been avoided in the past with x-rays by using the unit only for free air measurements, but the uncertainties must be eliminated by common agreement before it will be possible to use the roentgen with gamma rays under practical conditions without ambiguity and confusion.

The "definition" of the roentgen that has been established by the International Congresses of Radiology is more accurately called a definition of the standard; as such, it is only a partial definition of the unit. This is true generally of "definitions" of physical units. A definition of a unit would include a full discussion of the procedures of observation and arithmetic that are involved in measurements in terms of this unit—details that are established by common agreement and common practice. With older well-established units the procedures of measurement are well recognized and, for brevity, the definition of the standard is regarded as the definition of the unit. The fuller discussion of measurement is left to lengthy texts. With this comparatively new unit it still remains to decide and agree on many details of measurement.

The opinion that has been expressed occasionally that the use of the roentgen should be restricted to free air measurement has resulted probably from the confusion of the standard, that has been defined by the International Standardization Committee, with the unit. Use of the unit is limited only by logical consistency and

common agreement and it is applicable in any conditions for which the details of the method of measurement are accepted by general agreement of the profession. Analogous examples in other branches of physics are readily brought to mind.

It is desirable that the conventions that are adopted regarding the use of the roentgen have the following characteristics: (1) The unit defined by these conventions should be self sufficient, i.e., specification of the quantity of radiation in this unit should be independent of any reference to the thermodynamical unit, the erg. (2) Quantity expressed in this unit should be a property of the radiation only, not of the material traversed, and should be a scalar magnitude, not a vector.

The quantity of radiation traversing solid materials in widely converging directions has definite meaning when expressed in the older, thermodynamical units. It is sometimes very difficult to measure, but there is never any doubt about the nature of the physical magnitude that is to be measured. The use of the roentgen is uncertain because we have departed so greatly from our habits of thought in discussing radiation problems in the older units. These uncertainties are to be resolved by discussion of fundamental principles.*

The fundamental conception in theories of radiation is the *specific intensity*. The specific intensity is the rate of propagation of the radiation per unit area per unit solid angle in directions confined within a very narrow cone across a very small surface perpendicular to axis of the cone. This magnitude is basic in all radiation problems. In defining the roentgen standard the International Committee has prescribed an instrument that is to be used only with almost parallel radiation and when so used measures the total radiation in that almost parallel beam. There is no mention in the definition of the size of the small solid angle that embraces the directions of the rays that are measured. Hence before we can discuss specific intensity in terms of roentgens we must agree on some convention that will guide us in defining the angular distribution of the rays. Until this is done it will not be possible to discuss any but the simplest radiation problems by methods that are analogous to classical physics.

The use of the roentgen to express the specific quantity and intensity may be based on the following convention. Suppose that an opaque baffle with a small hole of area $A$ is placed in front of a standard chamber with the center of the hole on the axis of the chamber diaphragm system, and

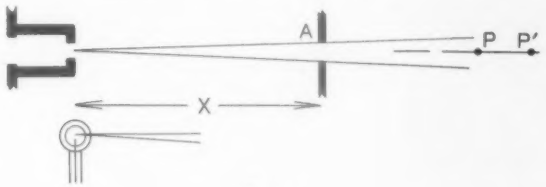


Fig. 2

at a distance $x$ in front on the aperture of the chamber diaphragm. The diameters of the baffle hole and the chamber diaphragm aperture are very small compared with the distance $x$ between them. The standard chamber with its diaphragm had been calibrated previously in the usual manner. Let us agree that at any point $P$ on the axis through the baffle and diaphragm the specific quantity of radiation propagated towards the apparatus is obtained by dividing the number of roentgens recorded by the chamber by the solid angle $A/x^2$ that the baffle hole subtends at the center of the chamber diaphragm. (The reader may prefer to think of the baffle hole as the effective aperture of the system, and of the chamber diaphragm as defining the limits of the solid angle. It is evident that the ionization current in the chamber will not be altered if the areas of the two apertures are interchanged. However, the chamber has been calibrated with its own diaphragm in its proper place, and hence if the ionization is to be interpreted correctly in roentgens, the interpretation of the meas-

* The following discussion will appear "elementary" and lacking in much novelty. It is intended to show that the meaning of the roentgen, applied to radiation that is penetrating solids, neither involves theoretical difficulties nor requires very radical differences from the methods of classical physics.

urement must be made in the manner described.) If a thimble chamber is used instead of the traditional type of standard chamber, obvious appropriate changes in the wording of this convention should be made.

It may be noticed that the specific intensity or quantity is the same at any two points $P$ and $P'$ on the axis through the apparatus provided that no scattering material intervenes between these points. This may appear to be somewhat surprising until it is remembered that the inverse square law of decrease with distance from the source applies to the total intensity, not to the specific intensity.

Having prescribed the manner in which the roentgen is to be used to express the specific quantity, the method of determining the scattering and absorption coefficients is obvious and so closely analogous to the method using the older units that no further description is necessary. This was not possible until the use of the roentgen to express the specific quantity was clarified. With the convention that has just been discussed the total absorption coefficients, the photoelectric absorption coefficients, $\tau$, and the total scattering coefficients, $\sigma$, are identical for use with the roentgen and the older units. (Coefficients expressing the intensity of the scattered modified radiation differ with the two systems of units since a change in quality is involved.) Thus the various magnitudes that are used in the solution of radiation intensity problems are given definite significance when using the roentgen and we are prepared to discuss these problems in terms of that unit.

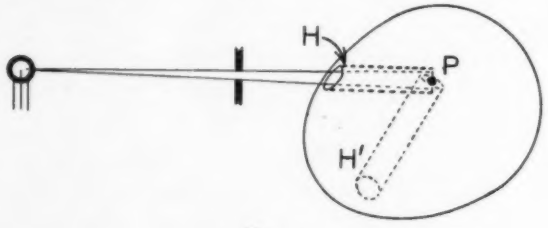


Fig. 3

Let us now attempt to describe what is meant by the total quantity of radiation at a point $P$ in the interior of a bulk of solid material exposed to radiation. This consists of both primary radiation and radiation scattered in the material and elsewhere. Imagine that a hole $H$ is drilled in the material to the depth of the point $P$, and that the standard chamber and baffle, that have just been described, are placed to receive the radiation from the bottom of the hole. The diameter of the hole is just large enough to avoid rays from the sides of the hole entering the chamber. We then measure the specific intensity of the radiation as propagated in the direction of the axis of the hole. This procedure differs only from the corresponding use of energy units in that the chamber replaces a bolometer for measuring the radiation that passes through the area defined by the chamber diaphragm. The intensity distribution of the radiation is altered slightly by drilling the hole and our measurement is in error to the extent represented by second order scattering effects including the radiation that would be scattered by the material removed in making the hole and rescattered elsewhere in the material to pass through the system of baffles. This error is very small and vanishes in the limit with decrease in the solid angle of the cone and the diameter of the hole.

Imagine that the material that is removed from the hole is replaced and another hole, $H'$, is drilled to $P$ from a different direction and that the specific quantity was measured in the same manner. Continuing this procedure for several holes, we can "map" the angular distribution of the specific quantity and by integrating the specific quantity over the complete solid angle of $4\pi$ radians we obtain the total quantity of radiation at the point $P$.

It follows from the above convention that a small thimble chamber, calibrated suitably, integrates the specific quantity of radiation in all directions, subject to error, of course, owing to the shadow of the lead-in bushing and support. Hence a thimble chamber may be used to measure the total quantity of a convergent beam with an ac-

curacy limited by instrumental sources of error. Thus if a thimble chamber is inserted in the hole *H* it will record the total radiation at the position it occupies if correction is made for the effects of the presence of the hole and chamber, and the shadow of the stem.

The procedure of measurement just described is a purely imaginary one that would be impracticable for routine measurements and is intended only to illustrate simply the *meaning* of quantity of radiation in solids. The discussion in this paper must be confined to *what* is to be measured, a necessary precedent to consideration of *how* it is measured most conveniently.

In many cases the only procedure for measurement of the quantity of radiation in a solid that is practicable at the present time is to determine the quantity of radiation outside the boundaries of the solid and calculate the quantity in the interior by use of the absorption constants. This is true whether we use roentgens or ergs. The advantage of the use of the roentgen is that it involves a simpler and more sensitive instrument for measurement; it cannot be expected to avoid any of the difficulties inherent in the problem of determining the quantity of radiation at an inaccessible point by any system of units.

The use of absorption constants to determine the quantity of radiation at inaccessible points requires that the quality of the radiation can be determined. The most satisfactory method of describing the quality for this purpose is the traditional method of expressing it in terms of the wave length. The use of copper half-value thicknesses is feasible if the tables of absorption constants are rewritten in terms of that notation and care is taken to distinguish between the use of copper half-value thicknesses for very narrow and very broad spectral distributions of the radiation. However, it offers no advantage over the use of wave length in these radiation problems and the latter is simpler. The copper half-value method was devised only as a very convenient device for describing approximately the quality of an extended spectrum for such purposes as checking the performance of roentgen-ray equipment or predicting biological reactions. Thus, for the present at least, wave lengths should be used where we are interested in the distribution of the energy in different parts of a spectrum, and copper half-values are preferable where only approximate knowledge of the quality is required.

Although copper half-value thicknesses are regarded only as approximate description of the quality, their utility should not be vitiated by too careless use. In the measurement of an almost parallel beam of rays the copper absorber is placed normally to the direction of the axis of the beam. If the radiation has penetrated a considerable thickness of material, a large percentage of it is scattered radiation and it will traverse the copper absorber in oblique directions. Whether or not we shall regard a measurement under such conditions as a description of the quality is a matter of convention and may depend on the use to be made of the data. For many purposes, such as consideration of the effects of the radiation on the material, it is scarcely satisfactory. The quality of the radiation traversing the point in question in different directions may be distinguished by measurements made with baffles arranged to exclude the radiation from other directions in a manner somewhat like the measurement of the specific quantity. The question may arise then how we should combine these data to express the quality of the *total* radiation traversing the point. If we are concerned with the effects on the material, the description of the quality should be independent of the directions of the component narrow beams that comprise the total radiation. Hence the proper procedure would be to determine the copper half-value thickness from a curve representing the weighted means of the copper absorption curves in all directions, the weights having been assigned in proportion to the intensities of radiation (in roentgens per minute) in the respective directions. It would be

much simpler to take the weighted mean of the copper half-values in the different directions. This is not accurately equivalent to the former procedure, but it might very well be considered to be a satisfactory approximation since copper half-value layers are intended only for approximate description. In whatever manner we may describe the quality of widely convergent radiation it is important to accompany the specification with some statement of how it is measured.

### VARIATION OF DENSITY OF IONIZATION PER ROENTGEN IN SOLIDS

It is generally recognized—although sometimes ignored in published descriptions of treatments—that the results of radiotherapy depend on other physical details in addition to the quantity and the quality of the radiation. The importance of the intensity, the area of skin exposed, the interval between partial treatments, the skin exposure to primary beta rays from the radium, etc., has been discussed frequently. Greater differences in many of these details occur in radium treatment than in roentgen treatment and therefore they require more careful consideration in the comparison or the prediction of the biological effects of radium treatment.

Another physical detail is a boundary effect which is unimportant for soft roentgen rays but should not be ignored with gamma rays or extra hard roentgen rays. This boundary effect is caused by secondary beta rays produced in one material crossing the boundary into another material and contributing to the ionization in the latter material. In consequence, the density of the ionization and other physical effects caused by the rays does not bear the same ratio to the number of roentgens near the boundary as it does in the interior of the volume of that material. In the interior of a homogeneous volume of material exposed to radiation, the ionization density is approximately proportional to the number of roentgens, but near the boundary it depends partly on the composition of the material outside the boundary. This boundary region that is affected by beta rays from without is quite thin with soft roentgen rays and probably may be disregarded, but it is several millimeters thick when using gamma rays. For example, if a sheet of aluminium, 1 mm. thick, is inserted between the skin and a brass-covered radium bomb, the number of roentgens is decreased by about 1 per cent, but the ionization density of the skin is increased by a large percentage even to the depth of the base of the skin cortex. It is difficult to believe that this would not have considerable effect on the tolerance of the skin to the treatment, because ionization is undoubtedly one of the initial causes of the series of processes that leads to the final biological effects.

The variation in the relative ionization density produced by 1 roentgen can be investigated experimentally with a special type of ionization chamber and phantom. Use is made of the fact, already mentioned, that nearly all of the ionization in a very small chamber is produced by secondary beta rays that have originated in the walls. It follows that the ionization in the wall very close to its inner surface is proportional to the ionization current in air space. Hence the variation of relative ionization per roentgen for any particular quality of radiation in any material, may be determined by using a very shallow chamber with a very thin wall of the same or similar material in a phantom that is also of the same or similar material. Data obtained in this manner for typical conditions may be used in comparing the physical details of treatment with the biological effects that are produced.*

Table IV gives typical relative values of the density of ionization per roentgen just below the skin surface, and at a depth of 5 mm. below the skin surface, for various materials placed between the skin and the radium needle which has a platinum wall 0.5 mm. thick, the value at a great depth being taken as 100 per cent. These values

* The importance of the boundary effect has been demonstrated clearly for the first time by Failla[4] in a paper describing the use of a thin wall chamber for these measurements. The discussion here is restricted to theoretical interpretation of such measurements.

are based on measurements made under the ideal condition (using a paper chamber and wood phantom) with the radium at a distance perpendicularly above the chamber that is greater than the dimensions of the chamber. Some variation is to be expected under the various conditions met in practice and they should be regarded as very approximate.

TABLE IV

RELATIVE DENSITY OF IONIZATION PER ROENTGEN IN THE SKIN IN PERCENTAGE OF THE VALUE AT GREAT DEPTH FOR VARIOUS MATERIALS BETWEEN THE SKIN AND A NEEDLE WITH A 0.5 MM. PLATINUM WALL

| Material | At Surface per cent | 5 mm. Below Surface per cent |
|---|---|---|
| None | 89 | 98.6 |
| 0.5 mm. lead | 87 | 97.6 |
| 1.0 mm. lead | 81 | 97.1 |
| Not less than 3 mm. aluminium | 84 | 97.6 |
| Not less than 1 mm. copper, iron or brass | 72 | 95.6 |
| Not less than 1 mm. silver | 69 | 95.1 |
| Not less than 10 mm. rubber, wood or bakelite | 100.1 | 100.0 |
| Not less than 10 mm. soft wax | 103 | 100.5 |

The radiologist can very often avoid consideration of the boundary effect in the case of the skin dose by the simple expedient of covering the skin under the radiation source with a layer of material that will greatly reduce the boundary effect. A layer of rubber, or other material that does not contain any heavy elements, that is at least 6 mm. and preferably 12 mm. thick, is suitable for this purpose. This layer has the additional advantage, that was discussed previously, of permitting the measurement of the quantity of the radiation at the skin surface with a small thin-walled chamber because the layer of material will exclude the beta rays from the wall of the radium container.

Practical use may be made of the boundary effect when it is more important to reduce the skin reaction to a minimum than to be able to determine the skin exposure accurately. A sheet of brass, iron, copper or zinc, about 0.5 mm. thick placed over the skin and under the radium container will reduce considerably the ionization density in the skin for a given quantity of radiation. Sheaths of these metals placed over radium needles and tubes will produce the same effect if there is no other material between the sheaths and the tissue. The elements at the center of the periodic table produce a lower ionization density in the skin than the elements at the beginning and end of the periodic table, when used in this manner with radium. With extra hard roentgen rays the most advantageous material depends on the quality of the rays, and is of lower atomic number for softer radiation.

Measurements made with the thin wall chamber near the boundary of a material may only be interpreted as the number of ions produced in unit volume of the material expressed in relative or arbitrary units. Accounts of measurements made under somewhat similar conditions have been published recently in which their authors have referred to the results of their measurements as "tissue dose" and expressed them in "roentgens." This terminology is likely to be very misleading since the quantities that have been so described are neither the *absolute* evaluation of the number of ions produced in the tissue nor a measure of the quantity of the radiation in roentgens. A new unit, called by another name, for expressing the quantities measured in this manner is probably desirable,[4] but the word "roentgen" should be reserved for specification of the quantity of roentgen rays or gamma rays according to established usage if ambiguity is to be avoided.

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# MEASUREMENTS OF RADIATION ENERGY AND TRUE TISSUE DOSAGE (ENERGY ABSORPTION) IN HIGH VOLTAGE THERAPY*

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## IONIZATION MEASUREMENT OF RADIUM GAMMA RAYS

WITHIN the past seven years many physicists engaged in radiology have sought to measure the density of air ionization produced by the gamma rays from radioactive sources. These measurements have been made for the purpose of ultimately correlating the clinical dosages of roentgen rays and of the gamma rays from radium, and they have been formalized into an expression of the air ionization density produced at a distance of 1.0 cm., in standard air, by the gamma radiations from 1.0 mc. of radium (B+C), filtered by 0.5 mm. of platinum. The expression of this quantity is given by *the number of roentgens per milligram-element-hour at 1.0 cm.:* (*r/mgeh-cm.*).

These measurements made on radium (which is a constant and universally available source of radiation) have been further intended as a means of demonstrating the ability to reproduce individual and independent air ionization observations of supervoltage roentgen rays, the physical qualities of which become almost identical with those of radium gamma rays when they are produced by roentgen tubes operating at potentials of the order of 1,000 kv.

A collation of individual values of *r/mgeh-cm.*, observed, chiefly, from the densities of air ionization produced in closed ionization chambers having walls of low atomic number (nearly that of air) is presented in Table 1. These values were taken from the extensive survey presented by Zimmer,[9] and from the recent study by Glasser and Rovner.[1] The average result of some 12 individual experimental evaluations and computations of the air ionization produced at a distance of 1.0 cm. by the gamma radiations from radium (B+C) is found to be: 8.55 *r/mgeh-cm.*, with a probable error, for the average value, of ±0.07 *r/mgeh-cm.* (The probable error of a single observation by any one individual, calculated from the data in Table 1, is ±0.24 *r/mgeh-cm.*)

TABLE I

AIR IONIZATION VALUES FOR GAMMA RAYS FROM RADIUM (B+C) FILTERED BY 0.5 MM. PLATINUM
(Expressed in *roentgens per milligram-element-hour at 1.0 centimeter: r/mgeh-cm.*)

| Author | Year | *r/mgeh-cm.* (0.5 mm. Pt filter) |
|---|---|---|
| A. S. Eve | 1911 (Recalculated) | 8.* |
| Glasser and Mautz | 1930 (Recalculated) | 8.8 |
| Reitz | 1931 | 9.0 |
| Mayneord-Gray | 1933 | 8.5 |
| Mayneord and Roberts | 1934 | 8.3 |
| Jaeger | 1934 | 8.* |
| Behnken and Jaeger | 1934 | 8.8 |
| Stahel | 1934 | 9.0 |
| Murdoch and Stahel | 1934 | 8.1 |
| Zimmer | 1934 | 8.5 |
| Sievert | 1934 | 8.* |
| Friedrich and Schulze | 1935 | 7.8 |
| Laurence | 1935 | 8.6 |
| Glasser and Rovner | 1936 | 8.8 |
| L. H. Gray | 1937 | 8.4 |
| Mean value: 8.55 ±0.07 *r/mgeh-cm.* | | |

* These values of *r/mgeh-cm.* are not included in the calculation of the mean value.

Of the many values presented in Table 1, there is one that, in this writer's opinion, has the most nearly rigorous physical foundation; this value stands at about 8.4 *r/mgeh-cm.* The value, presented by Gray,

* Read at the Fifth International Congress of Radiology, Chicago, Ill., Sept. 13–17, 1937.

is calculated from a special form of ionization measurement of the total gamma-ray emission of radium (B+C), and from the most probable values of the scattering absorption coefficient of air, and of the energy required for the production of a single pair of ions in air. The principle underlying this form of measurement will subsequently be described; it is believed to be one of considerable importance to the measurement of energy and of true dosage of very high voltage radiations.

The general (though not exact) agreement among the separate and independently determined ionization values of Table 1 is useful in showing (especially in relation to some approximately established calorimetric measurements) that the true value of the air ionization produced by the gamma rays from Ra (B+C) is known to lie within a well-defined range. It may be stated with considerable certainty that the mean value presented here, of 8.55 *r/mgeh-cm.*, is in error by no more than ±5 per cent.

As a consequence of this situation, it can be seen that empirical and rational ionization measurements of supervoltage radiation are beginning to approach a satisfactory stage.

Furthermore, the most recent work in this field indicates that a theory and a method are finally available to establish these measurements upon a more nearly rigorous and exact physical basis.

## THE PROBLEM OF EXPRESSING TRUE RADIATION DOSAGE

Since the biological effect ultimately produced in living tissue by penetrating radiations is the result of an initial ionization process, the expression for true radiation dosage must necessarily give an exact quantitative measure of the magnitude of this process in the tissues. Each ion pair formed in an irradiated medium (as the result of any one of several primary absorption phenomena) represents a certain amount of energy removed from the beam and made available for possible utilization in the absorber; for example, in energizing a photochemical reaction. Hence *the energy absorbed from the beam at any point in tissue is a measure of the ionization produced there by the radiation*, and is therefore a measure of the actual tissue dosage.

It is interesting, in this light, to observe that the roentgen—which is apparently a unit that directly expresses the amount of ionization produced in light materials—gives an incomplete account, *by itself*, of the actual ion production in tissues, and hence gives an inexact description of the real dosage.

(This situation may be well known, but will be briefly reviewed here: Two underlying properties of a given beam, which ultimately determine the tissue dosage, are the quality of the radiation [the spectral distribution of the energy] and the total actual energy in the beam. The roentgen is not a unit of actual energy available in the beam,—instead of being a pure energy unit it is, rather, a unit of energy-absorbed-by-air. The relation of the number of roentgens to the total energy in the beam is a variable one that changes with the changing absorption coefficient of air over the different wave length ranges. The absorption coefficient for a thin sheet of tissue changes in a manner nearly parallel to that of air, but the quite different condition of back-scatter in a large volume of tissue makes *the energy absorption*, there, *uniquely dependent upon the total amount of energy* that is available in the initial beam. Hence the roentgen, a variable unit of available energy, bears a complex relation to the actual dosage or energy absorption in tissue.)

## EXPRESSION OF DOSAGE IN TRUE ENERGY UNITS

Since the roentgen does not maintain a constant or simple relationship either to the actual energy in the beam, or to the energy absorbed in tissue, the conversion of "milligram-element-hours" into "roentgens" should be considered only as one step toward a conversion of dosage units in radium and roentgen-ray therapy, and not as the end, itself.

Lauritsen[6,7,8] has shown how, for any given beam, the relation of the total energy per roentgen observed may be expressed as a function of the effective wave length by calculation from established values of photoelectric and scattering (recoil) absorption coefficients. In a similar manner he has demonstrated how the energy absorbed in a superficial layer of tissue may be determined.

(Considering the relation of air ionization measurements of gamma rays of radium and of roentgen rays, in the light of the quantitative energy calculations demonstrated by Lauritsen, one may see that the air ionization values for "free" air, apparently unrelated to the back-scattering and absorption phenomena found in tissue, do become a direct means of evaluating tissue dosage. In this case the basis of the calculation is the underlying real quantity revealed by the "free" ionization measurement: the total energy in the beam.)

Lauritsen's calculations hold approximately for energy absorption in the superficial layers of a medium such as water, or tissue. In the analysis thus far presented, however, energy absorption at a depth remains indeterminate, because of the change in the wave length of the radiation (due to the Compton recoil process) and because of the consequent, undetermined, change in the value of the absorption coefficients.

It is in the recent work of Gray[2,3,4,5] that one may observe with much interest the presentation of an apparent answer not only to the more nearly rigorous evaluation of ionization density in air and of the energy in the beam (by means of a closed ionization chamber measurement), but also to *the direct measurement (by ionization chamber) of the energy absorption at a depth in tissue*. Depth dose measurements have, of course, been made over a very long period of time; but it has been generally felt that the energy values represented by these measurements were not exactly known. This condition has obtained because of the apparent difficulty of determining the change in the quality of the radiation at a depth, and the difficult evaluation of the consequent change in the ionizing function—or response to the radiation—of the ionization chamber used.)

In a series of three physical papers, Gray[2,3,4] has (1) presented an abstract solution to the problem of measuring the energy flux of high voltage radiations by means of the enclosed ionization chamber (that is largely independent of a change in wave length of the radiation); (2) apparently verified, experimentally, the implications of his equation relating the ionization values observed and the energy densities present, and (3) utilized the method to measure the total energy flux of high voltage radiations from radioactive substances. These last measurements have shown total energy values for the gamma rays of radium (B+C) which agree within 5 per cent with some recent refined calorimetric measurements. Two recent papers by the same author[5] describe some radiological consequences of the work.

Gray uses a method of analysis of closed chamber ionization which permits the experimental evaluation of a constant of proportionality relating the energy absorp tion per unit volume in a solid, and the ionization per unit volume in a gas-filled cavity within the solid. The solid may be either the walls of the closed chamber, or, in fact, an absorbing medium such as tissue. The cavity is the air space of the appropriate ionization chamber. The significant fact here is that *the "wall effect" may be evaluated by means of experimentally determinate quantities.*

It must be emphasized that this viewpoint* of closed chamber ionization is a unique one which does not proceed at all by analogy from the ionization principles of the open air chamber. In this case the presence of a large "wall effect," or con-

* As recorded by Gray[5] this oft forgotten principle has been independently stated by Bragg (1912), and also by Fricke and Glasser (1925).

tribution to the gaseous ionization by particles from the wall, is a highly desirable property of the measurement. It can be shown that in a very small chamber the ionization observed in the gas is overwhelmingly due to the secondary particles (electrons) from the wall. The "wall" showers ionizing particles into the enclosed air space at a rate proportional to their rate of formation in the surrounding dense material. Hence the enclosed air space *records* the rate of energy absorption in the surrounding material, in a manner that can be evaluated by means of a definite constant of proportionality. As a result of this work it may be that the small ionization chamber will become quite useful in actual energy measurements of high voltage radiations, and in the measurement of energy absorbed at a depth in tissue.

SUMMARY

The increasing agreement found among recent independent evaluations of the air ionization constant for gamma rays of radium emphasizes the present opportunity of next converting this and other ionization measurements into true dosage values. As demonstrated by Lauritsen only the evaluation of the true energy absorption serves as a proper means for comparing clinical dosages or for investigating biological effects of different radiations. The recent work of Gray has shown that these energy measurements may become established upon a sound theoretical and experimental basis. Since the formation of ions or the liberation of high speed ionizing particles in an irradiated medium is always the result of true energy absorption of the radiation in the medium, it is suggested that this absorbed energy quantity, itself, be used to express dosage. In this case the dosage may be stated in ergs or in microcalories of radiation energy absorbed per cubic centimeter of tissue.

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# FACTORS INFLUENCING THE QUANTITATIVE MEASUREMENT OF THE ROENTGEN-RAY ABSORPTION OF TOOTH SLABS*

## IX. TUBE-MACHINE COMBINATION FACTORS

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WHILE we feel certain that the use of the step tablet as a calibrating factor enables us to neglect radiation factors as influenced by the roentgenographic tube, it seemed useful to rule out such of these as might be tested, for completeness, by a few experiments directed to each in turn; thus, in a measure, by another method (densitometric) verifying physical phenomena usually investigated by the ionization method. With modern line focus tubes, the built-in filter is an unknown factor because of the lack of precision in thickness of commercial filters. Each tube should be tested (densitometrically) for uniformity of the beam. The critical angles should be avoided. The filter may make them unsuitable for low voltage (long wave length) operation in certain cases. With a minimum of filter (glass and black paper) between the tube and film and exposing in triplicate, it is possible by suitable choice of film quality (density gradients across the film less than 0.05 density units) to reduce the error of reproducibility to less than 4 per cent. In general, however, if there is no gradient due to the shape of the target or irregularity in filter, there is no reason to expect any diminution in accuracy of the I. Vs. from either the tube or

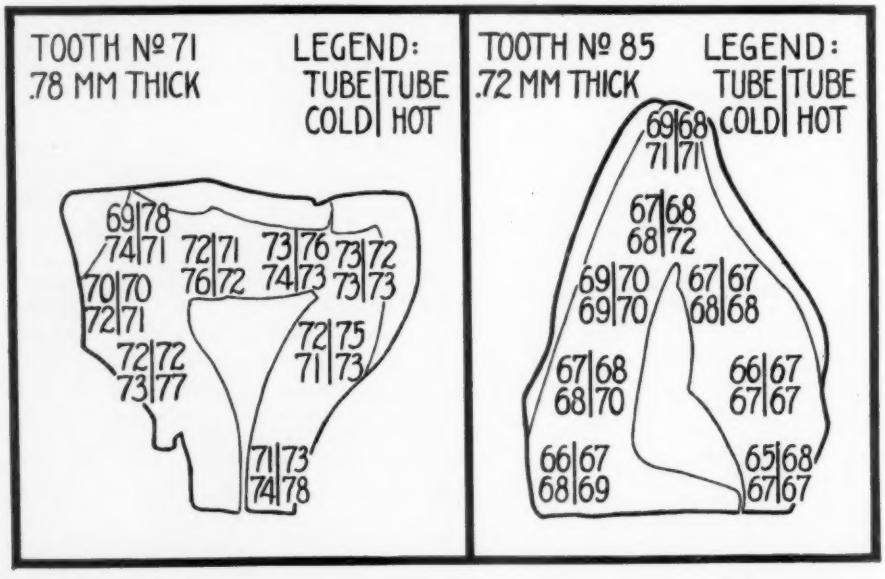


FIG. 112. The I. Vs. for various areas are inserted at the approximate location of reading. Values from exposures with the tube cold are on the left side of the vertical lines; values with the tube hot on the right side. The average I. Vs. per unit thickness for all readings are 0.94 and 0.93 for teeth No. 71 and 85, respectively, with the tube cold, and 0.95 and 0.94, respectively, with the tube hot.

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machine characteristics or any combination of the same.

### A. HOT OR COLD TUBE

To test whether or not the condition of the tube, i.e., hot or cold, has any effect on the magnitude of the I. Vs., two exposures were made with the tube cold and two exposures with the tube hot. D. Rs. in various parts of 2 teeth, No. 71 and 85, gave I. Vs. which are independent of the tube condition.

In Table XCV are given the average D. Rs. in the various steps of the penetrometers I and II in 2 films taken *with the tube cold* at 30 kv., 30 ma., 15 inches, 0.85 sec., no tube stand filter and black-paper-covered films. The D–T curves (not shown) are typical. The I. Vs. for the areas in the dentine show a fairly high degree of uniformity. In order to facilitate comparisons for hot vs. cold in identical areas, the I. Vs. are inserted on the left side of the vertical line indicating the approximate area studied in tooth No. 71 and 85 (see Fig. 112). The average I. Vs. are given in Table XCVII; all of the areas taken together average 0.73 mm. Al from tooth No. 71, 0.67 mm. Al for tooth No. 85. Since tooth No. 71 is 0.78 mm. thick, and tooth No. 85 is 0.72 mm. thick, the average I. V./thickness ratio is 0.94 and 0.93, respectively.

TABLE XCV

COLD TUBE, 30 KV., 30 MA., 15 INCHES, 0.85 SEC., NO FILTER, BLACK PAPER

| Step | Film S34E85 D. R. Penetrometer I | Film S34E85 D. R. Penetrometer II | Film S34E86 D. R. Penetrometer I | Film S34E86 D. R. Penetrometer II |
|---|---|---|---|---|
| 1— | 2.14 | 2.12 | 2.27 | 2.26 |
| 2— | 1.70 | 1.70 | 1.87 | 1.85 |
| 3— | 1.42 | 1.41 | 1.60 | 1.55 |
| 4— | 1.24 | 1.22 | 1.35 | 1.34 |
| 5— | 1.07 | 1.05 | 1.20 | 1.18 |
| 6— | 0.92 | 0.92 | 1.06 | 1.03 |
| 7— | 0.82 | 0.81 | 0.92 | 0.89 |
| 8— | 0.77 | 0.77 | 0.88 | 0.85 |

| Tooth No. | Dentine Area 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | Dentine Area 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 71 | 1.49 | 1.46 | 1.45 | 1.45 | 1.48 | 1.46 | 1.46 | 1.47 | 1.58 | 1.57 | 1.58 | 1.60 | 1.62 | 1.59 | 1.61 | 1.58 |
| 85 | 1.49 | 1.51 | 1.49 | 1.52 | 1.53 | 1.52 | 1.53 | 1.54 | 1.61 | 1.65 | 1.64 | 1.66 | 1.66 | 1.65 | 1.67 | 1.67 |
| Interpolated Values (mm. Al) | | | | | | | | | | | | | | | | |
| 71 | 0.69 | 0.72 | 0.73 | 0.73 | 0.70 | 0.72 | 0.72 | 0.71 | 0.74 | 0.76 | 0.74 | 0.73 | 0.72 | 0.73 | 0.71 | 0.74 |
| 85 | 0.69 | 0.67 | 0.69 | 0.67 | 0.66 | 0.67 | 0.66 | 0.65 | 0.71 | 0.68 | 0.69 | 0.68 | 0.68 | 0.68 | 0.67 | 0.67 |

In Table XCVI are given the average D. Rs. in the various steps of the penetrometers I and II in 2 films taken *with the tube hot* from prolonged heating plus at least 6–20 sec. blank exposures and exposed at 30 kv., 30 ma., 15 inches, 0.85 sec., no filter, black-paper-covered films. The D–T curves (not shown) are closely laid, and typical. The I. Vs. for the areas in the dentine have a fairly high degree of uniformity. The I. Vs. are inserted on the right hand side of the vertical lines in tooth No. 71 and in tooth No. 85 (see Fig. 112). The average I. Vs. are given in Table XCVII; all the areas together average 0.74 mm. Al for

TABLE XCVI

HOT TUBE, 30 KV., 30 MA., 15 INCHES, 0.85 SEC., NO FILTER, BLACK PAPER

| Film S34E92 | | | Film S34E93 | |
|---|---|---|---|---|
| Step | D. R. Penetrometer I | D. R. Penetrometer II | Step | D. R. Penetrometer I |
| 1— | 1.95 | 1.92 | 1— | 1.98 | 1.95 |
| 2— | 1.57 | 1.58 | 2— | 1.60 | 1.59 |
| 3— | 1.30 | 1.30 | 3— | 1.36 | 1.32 |
| 4— | 1.13 | 1.10 | 4— | 1.14 | 1.13 |
| 5— | 0.96 | 0.97 | 5— | 1.00 | 1.01 |
| 6— | 0.86 | 0.84 | 6— | 0.88 | 0.89 |
| 7— | 0.76 | 0.72 | 7— | 0.80 | 0.80 |
| 8— | 0.72 | 0.70 | 8— | 0.74 | 0.73 |

| Tooth No. | Dentine Area 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | Dentine Area 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 71 | 1.28 | 1.35 | 1.30 | 1.34 | 1.36 | 1.34 | 1.31 | 1.33 | 1.39 | 1.38 | 1.37 | 1.37 | 1.39 | 1.33 | 1.37 | 1.32 |
| 85 | 1.38 | 1.38 | 1.36 | 1.38 | 1.40 | 1.39 | 1.39 | 1.38 | 1.39 | 1.38 | 1.40 | 1.40 | 1.41 | 1.42 | 1.44 | 1.44 |
| Interpolated Values (mm. Al) | | | | | | | | | | | | | | | | |
| 71 | 0.78 | 0.71 | 0.76 | 0.72 | 0.70 | 0.72 | 0.75 | 0.73 | 0.71 | 0.72 | 0.73 | 0.73 | 0.71 | 0.77 | 0.73 | 0.78 |
| 85 | 0.68 | 0.68 | 0.70 | 0.68 | 0.67 | 0.67 | 0.67 | 0.68 | 0.71 | 0.72 | 0.70 | 0.70 | 0.69 | 0.68 | 0.67 | 0.67 |

tooth No. 71; 0.68 mm. Al for tooth No. 85. The Average I. V./thickness ratios are 0.95 and 0.94, respectively.

It is interesting to compare recent in-

TABLE XCVII

| Tooth No. | Av. I. V. *S34E85* | Av. I. V. *S34E86* | Av. I. V. *cold* | Av. I. V. *thickness* |
|---|---|---|---|---|
| COLD TUBE | | | | |
| 71 | 0.72 | 0.74 | 0.74 | 0.94 |
| 85 | 0.66 | 0.68 | 0.73 | 0.93 |
| HOT TUBE | | | | |
| | *S34E92* | *S34E93* | *hot* | |
| 71 | 0.74 | 0.75 | 0.74 | 0.95 |
| 85 | 0.67 | 0.69 | 0.68 | 0.94 |

vestigations using ionization measurements* which show that the "output changes (usually decreases)—during the first few minutes of operation." The D. Rs. under step 1 average about 2.2 in the films made with the tube cold and decrease to 1.95 average in the films made with the tube hot.

*Summary.* It is evident both from the figures, where the I. Vs. for the various areas are equal for hot or cold tube, and from the data in Table XCVII where the average I. Vs. are practically identical that the I. Vs. are independent of the tube condition, hot or cold.

### B. KILOVOLTAGE VERSUS DENSITY

The considerable quantity of data on "radia-tized dental film" provides an opportunity for studying several relations between the factors controlled or measured in exposing the films. Since the series includes films exposed at 10, 15, 20, and 25 seconds at kilovoltages of 30, 40, 50, and 60, it is possible to plot curves in which the density differences with kilovoltage change for constant time are shown (Figs. 113–121). The densities for the film as well as for each step in the penetrometer are given

* Gross, *Radiology*, 1933, *20*, 14, and Taylor, Singer and Stoneburner, AM. J. ROENTGENOL. & RAD. THERAPY, 1934, *31*, 378.

Table XCVIII

| Film | | Step | | | | | | | | Step Av. | High | Low |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| sec. | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | | | |
| 10 | 81 | 74 | 73 | 73 | 72 | 74 | 74 | 73 | 73 | 73¼ | 74 | 72 |
| 15 | 81 | 77 | 74 | 75 | 76 | 75 | 77 | 76 | 76 | 75¾ | 77 | 74 |
| 20 | 79 | 79 | 79 | 78 | 78 | 76 | 78 | 78 | 77 | 78 | 79 | 76 |
| 25 | 80 | 79 | 79 | 79 | 79 | 78 | 77 | 78 | 78 | 78½ | 79 | 77 |

in separate charts in each of which there are four curves, representing the density-kv. relations at 10, 15, 20, and 25 seconds, respectively. To our great surprise, the density-kv. curves appear as straight lines excepting in the low density ranges (densities less than 0.06) which are in the "toe" of the characteristic curve for "radiatized dental film" (see Fig. 1, Wilsey and Pritchard). These departures from straight line relations are particularly noticeable in

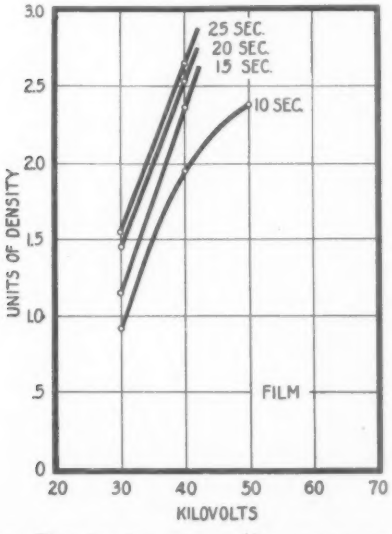


Fig. 113. Density-kv. curves for exposures on the "film," i.e., D. Rs. in areas not under the penetrometer.

the charts for Steps 5, 6, 7, and 8 where abrupt breaks are evident in the low density range. A still more surprising fact was found when the slopes of the straight lines were obtained using a protractor. In Table XCVIII are given the angle of inclination of the D-kv. lines relative to the abscissa for the film and each of the steps at 10, 15, 20, and 25 seconds. As may be seen, the

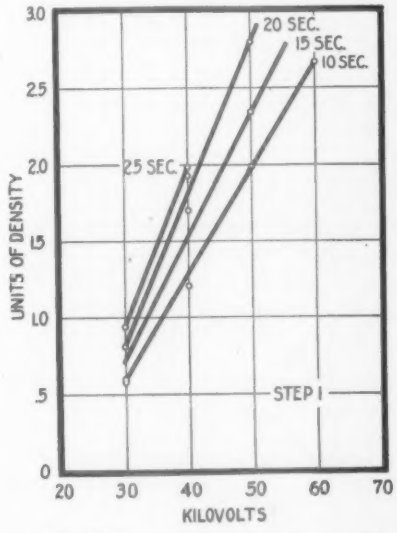


Fig. 114. Density-kv. curves under 0.25 mm. Al.

slopes of the D-kv. lines are constant within about 6 per cent. There also seems to be a tendency for the slopes of the D-kv. lines at 10 seconds to be consistently less than those at longer exposures, or in other words, the exposure time seems to have some influence on the slope of the D-kv. line, the exact significance of which is obscure.

However, let us review briefly what factors are fixed and what are not known in order to gain a clearer insight into the significance and usefulness of the constant slope of the straight line relation between

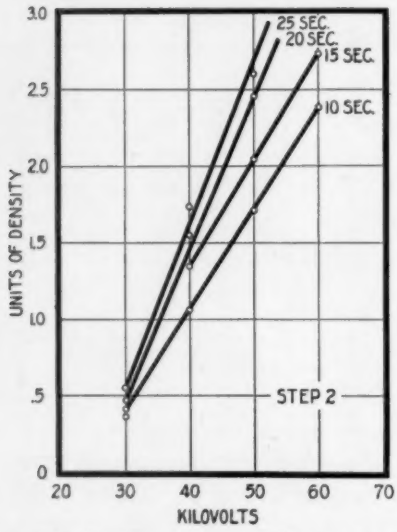


FIG. 115. Density-kv. curves under 0.48 mm. Al.

D and kv. The milliamperage, time and distance are all constant for the exposures. The same tube and machine combination, the same film and the same filter thickness (step of penetrometer) are used. There re-

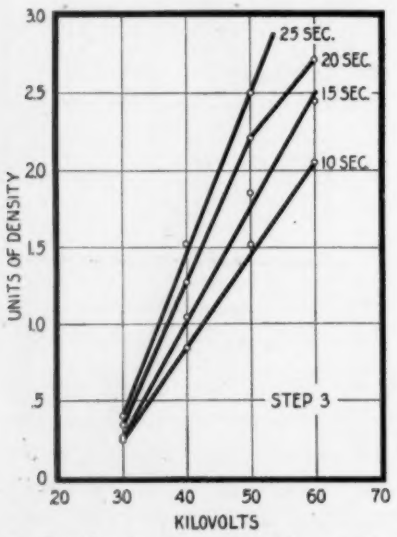


FIG. 116. Density-kv. curves under 0.76 mm. Al.

mains only kv. on the tube and D in the developed film since the development procedure is standardized. Between the kv. and resulting D, for densities greater than 0.6, there is found a linear relation which may be stated as follows: The difference in density produced by a given difference in kilovoltage (time, milliamperage, distance, etc., being constant) is a constant. This may be written in an equation as follows:

$$(D-D')_{t\ \text{const.}} = k(kv-kv')$$

in which k is a constant numerically about 0.075 to 0.08. By taking an exposure at

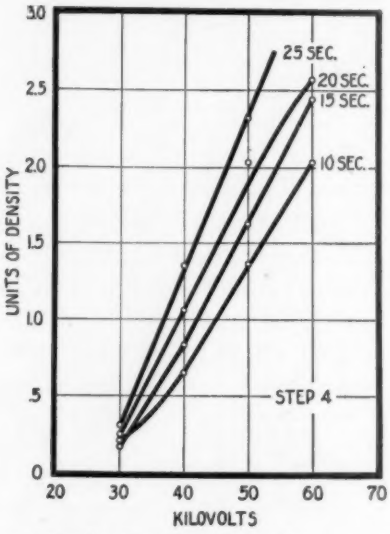


FIG. 117. Density-kv. curves under 1.00 mm. Al.

some definite kv. and T and measuring the D, e.g., 40 kv., 15 seconds, producing a density of 0.70 under Step 5, we may calculate that at 50 kv., 15 seconds, a density of 1.45 will be produced, i.e.,

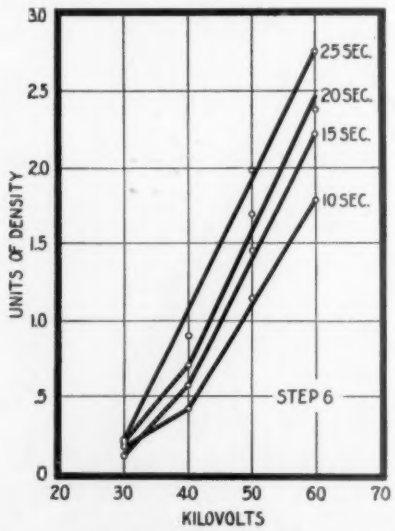


FIG. 119. Density-kv. curves under 1.48 mm. Al.

$$(D_{50}-0.70)=0.075(50-40)$$
$$(D_{50}-0.70)=0.75$$
$$D_{50}=0.75+0.70=1.45.$$

The actual measured density of the film exposed at 50 kv., 15 seconds is found to be 1.48.

*Summary.* The density increments with kilovoltage increase are fairly constant (other factors being constant) as long as the densities are in the range of the straight line portion of the characteristic curve.

### C. TUBE-MACHINE COMBINATION

In making a series of identical exposures, small, uncontrollable fluctuations in line voltage sometimes occur. To test the effect

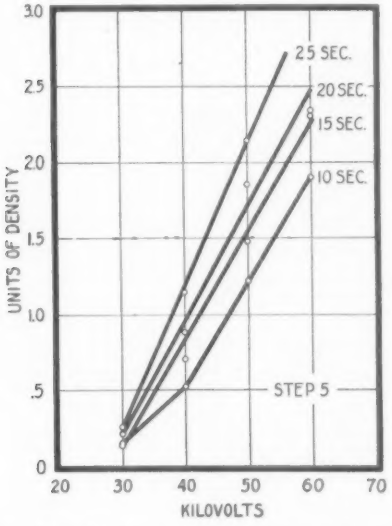


Fig. 118. Density-kv. curves under 1.24 mm. Al.

of small voltage changes on the I. Vs. for enamel and for dentine when other experimental conditions are constant a series of exposures was made at 40 and at 50 kv., keeping other factors constant. That we might also ascertain the effect of different tube-machine combinations on the I. Vs. when the kilovoltage is changed, the exposures were made in cubicles No. 1, 2, and 3. In cubicles No. 1 and 2, there are full wave mechanical rectifiers; in No. 3 there is a half-wave valve tube rectifier. Otherwise, there is no difference in the equipment. Three tubes were used: (1) a universal round focus, 30 ma. Coolidge tube, (2) a water-cooled, line focus, XP3 Coolidge tube, (3) an air-cooled, line focus Coolidge tube. Inasmuch as no difference was found in the results using a water-cooled or an air-cooled line focus, XP3, Coolidge tube, we have not distinguished between them. Four exposures were made with each tube at each kv. (40 and 50) in cubicles No. 1 and 2, only the round focus tube was used in cubicle No. 3.

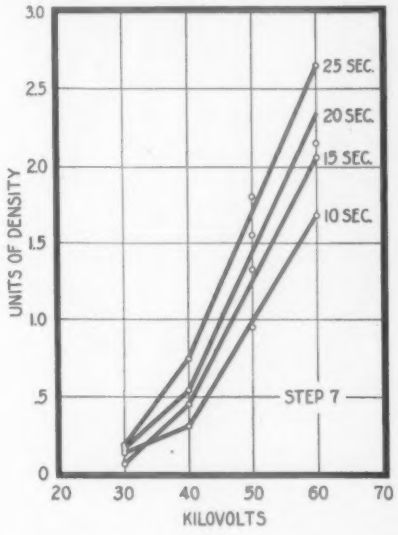


Fig. 120. Density-kv. curves under 1.76 mm. Al.

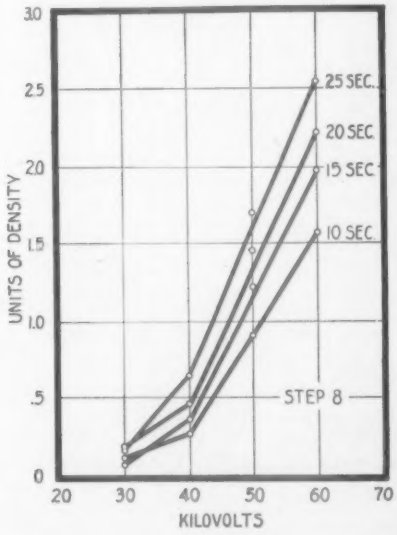


Fig. 121. Density-kv. curves under 2.01 mm. Al.

TABLE XCIX

| Cubicle No. Rectifier | 1 Mechanical | | | | 2 Mechanical | | | | 3 Valve tube | |
|---|---|---|---|---|---|---|---|---|---|---|
| Tube focus | Round | | Line | | Round | | Line | | Round | |
| kv. | 44 | 53 | 44 | 53 | 44 | 53 | 41 | 53* | 41 | 53 |
| Av. D. R. | | | | | | | | | | |
| Step 1 | — | — | 2.62 | — | 2.38 | — | — | — | 1.92 | — |
| 2 | 2.68 | — | 2.36 | 2.65 | 2.13 | 2.66 | 2.62 | — | 1.58 | 2.44 |
| 3 | 2.41 | — | 2.17 | 2.46 | 1.96 | 2.49 | 2.35 | 2.63 | 1.34 | 2.27 |
| 4 | 2.21 | 2.75 | 2.00 | 2.31 | 1.79 | 2.33 | 2.15 | 2.43 | 1.15 | 2.04 |
| 5 | 2.02 | 2.62 | 1.89 | 2.15 | 1.68 | 2.26 | 2.00 | 2.29 | 1.01 | 1.92 |
| 6 | 1.87 | 2.46 | 1.78 | 2.03 | 1.56 | 2.13 | 1.89 | 2.14 | 0.87 | 1.78 |
| 7 | 1.70 | 2.34 | 1.65 | 1.92 | 1.46 | 2.02 | 1.74 | 1.99 | 0.76 | 1.65 |
| 8 | 1.60 | 2.23 | 1.56 | 1.84 | 1.39 | 1.94 | 1.66 | 1.92 | 0.68 | 1.55 |

Average densitometer readings (each figure in the table represents the average of 4 identically exposed films) in the various cubicles using round and line focus tubes at different kilovoltages. All exposures are made at 30 inches, 30 ma., 1½ seconds, no tube stand filter, and black-paper wrapped films.

* Only 2 films are averaged to give the D. Rs. in this column.

In Table XCIX are given the average densitometer readings from the films taken in cubicles No. 1, 2, and 3 using round and line focus tubes in each cubicle. Each figure in the table represents the average value from four identical films. All exposures were made at 30 inches, 30 milliamperes, 1½ seconds, no tube stand filter, and black-paper-wrapped films. Exposures were made with each tube at approximately 44 and 53 kv. It is immediately evident that the D. Rs. at higher kilovoltages are greater than at the lower (compare Part B, this paper). In order to study the density-tube-kv.-cubicle relations, Figures 122, 124, and 126 show D–T curves in cubicles No. 1, 2, and 3 respectively for round and line focus tubes (RF and LF) at the kv. indicated. The output (density) is very similar for cubicles No. 1 and 2 and some-

TABLE C

| Cubicle | 1 | | | | | | | | 2 | | | | | | | | 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tube Focus | Round | | | | Line | | | | Round | | | | Line | | | | Round | | | |
| Kv. | 44 | | 53 | | 44 | | 53 | | 44 | | 53 | | 41 | | 53 | | 41 | | 51 | |
| Enamel | Dent | | E | D | E | D | E | D | E | D | E | D | E | D | E | D | E | D | E | D |
| D. R. | 1.98 | 2.43 | 2.40 | — | 1.85 | 2.18 | 2.03 | 2.35 | 1.63 | 1.91 | 2.11 | 2.49 | 1.97 | 2.34 | 2.11 | 2.58 | 0.96 | 1.31 | 1.92 | 2.27 |
| I. V. | 1.35 | 0.78 | 1.62 | — | 1.51 | 0.88 | 1.44 | 0.88 | 1.38 | 0.86 | 1.41 | 0.73 | 1.40 | 0.83 | 1.49 | 0.79 | 1.34 | 0.82 | 1.34 | 0.82 |
| D. R. | 1.90 | 2.36 | 2.54 | — | 1.85 | 2.14 | 2.08 | 2.47 | 1.61 | 1.91 | 2.16 | 2.50 | 1.95 | 2.38 | 2.20 | 2.64 | 0.94 | 1.26 | 1.89 | 2.20 |
| I. V. | 1.36 | 0.78 | 1.53 | — | 1.41 | 0.75 | 1.42 | 0.81 | 1.36 | 0.83 | 1.42 | 0.81 | 1.40 | 0.78 | 1.42 | 0.77 | 1.33 | 0.85 | 1.35 | 0.86 |
| D. R. | 1.91 | 2.32 | 2.50 | — | 1.81 | 2.20 | 2.06 | 2.46 | 1.62 | 1.93 | 1.97 | 2.37 | 1.85 | 2.29 | | | 1.01 | 1.38 | 1.79 | 2.07 |
| I. V. | 1.36 | 0.78 | 1.37 | — | 1.29 | 0.83 | 1.38 | 0.73 | 1.43 | 0.82 | 1.60 | 0.83 | 1.47 | 0.77 | | | 1.31 | 0.80 | 1.40 | 0.93 |
| D. R. | 2.02 | 2.52 | 2.53 | — | 1.71 | 2.07 | 2.25 | 2.64 | 1.63 | 1.99 | 2.51 | — | 1.87 | 2.31 | | | 1.01 | 1.34 | 1.83 | 2.16 |
| I. V. | 1.30 | 0.76 | 1.47 | — | 1.42 | 0.84 | 1.18 | 0.68 | 1.44 | 0.81 | 1.08 | — | 1.44 | 0.78 | | | 1.31 | 0.82 | 1.34 | 0.87 |

The D. Rs. and I. Vs. for enamel and for dentine in the films taken in the various cubicles using round and line focus tubes and at different kilovoltages. All exposures were made at 30 inches, 30 ma, 1½ seconds, no tube stand filter, and black-paper-wrapped films.

what less for cubicle No. 3. There is evidence of a greater separation between the D-T curves at 44 and 53 kv. using round focus tubes than line focus tubes. The

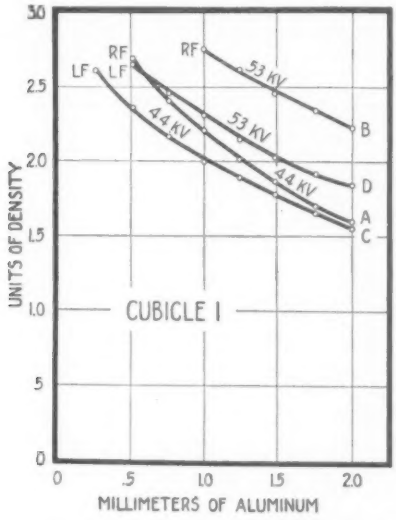


Fig. 122. The D-T curves for round and line focus tubes at 44 and 53 kv. are compared using a mechanical rectifier.

slopes of the D-T curves are similar in the films from cubicles No. 1 and 2 but markedly less from cubicle No. 3. These differences will be discussed below.

In Table c are given the D. Rs. and the corresponding I. Vs. for enamel and for

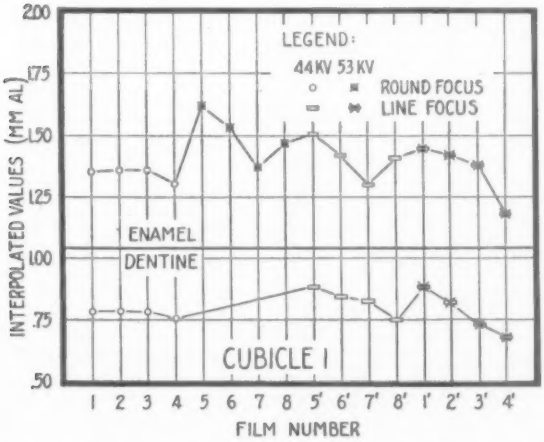


Fig. 123. The I. Vs. for enamel and for dentine are plotted against the film number to show reproducibility at 44 and 53 kv. using round and line focus tubes.

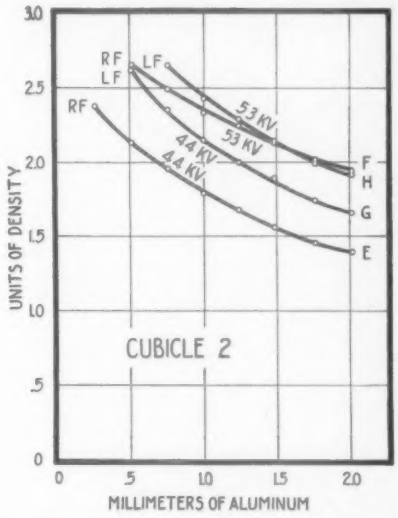


Fig. 124. The D-T curves for round focus and line focus tubes at 44 and 53 kv. are compared using a mechanical rectifier.

dentine in the 68 films reported in Table xcix. Our principal interest is to determine the relation, if any, between I. Vs. and cubicles, between I. Vs. and tube types,

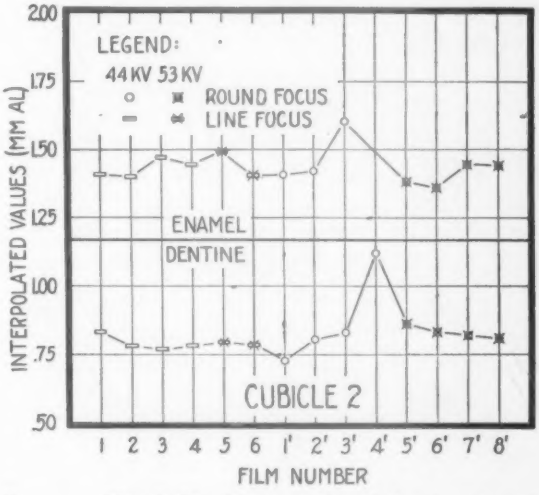


Fig. 125. The I. Vs. for enamel and for dentine are plotted against film number to show reproducibility at 44 and 53 kv. using round and line focus tubes.

and between I. Vs. and kv. In Figures 123, and 125 and 127 are plotted the I. Vs. for enamel and for dentine taken from the films exposed in cubicles No. 1, 2, and 3 respectively. Two tendencies may be described

from a consideration of the graphs: (1) there seems to be less variation in the I. Vs. at the lower kv., and (2) there seems to be less variation in the I. Vs. using a round

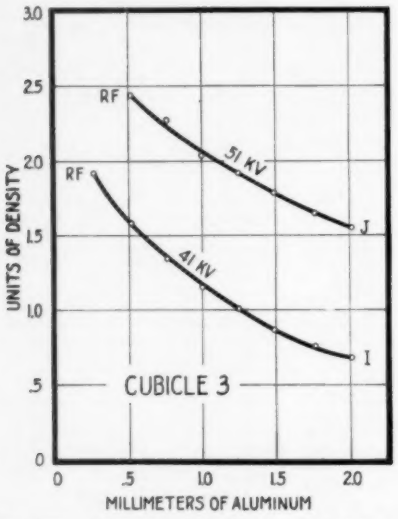


Fig. 126. The D-T curves for a round focus tube at 41 and 51 kv. are compared using a single valve tube rectifier.

focus tube than a line focus tube. There are no regular differences in I. Vs. which may be associated with tube type or machine type. Therefore, as might be predicted, the I. Vs. for enamel and for dentine are independent of tube and machine combinations.

From the foregoing data, an interesting calculation is possible, namely, the ratio of the density increase to the kilovoltage increase, other factors being constant. Thus in cubicle No. 1 for the round focus tube:

under Step 4 at 53 kv., D. R. = 2.75
at 44 kv., D. R. = 2.21

0.54

under Step 8 at 53 kv., D. R. = 2.23
at 44 kv., D. R. = 1.60

0.63

An increase of about 0.54 density units is found for a 9 kv. increase which gives $\frac{0.54}{9}$ = 0.06 density units increase per kv. For the line focus tube:

under Step 4 at 53 kv., D. R. = 2.31
at 44 kv., D. R. = 2.00

0.31

under Step 8 at 53 kv., D. R. = 1.84
at 44 kv., D. R. = 1.56

0.28

An increase is found of about 0.29 density units for a 9 kv. increase, or $\frac{0.29}{9}$ = 0.03 density units per kv. In cubicle No. 2, for the round focus tube:

under Step 3 at 53 kv., D. R. = 2.49
at 44 kv., D. R. = 1.96

0.53

under Step 8 at 53 kv., D. R. = 1.94
at 44 kv., D. R. = 1.39

0.55

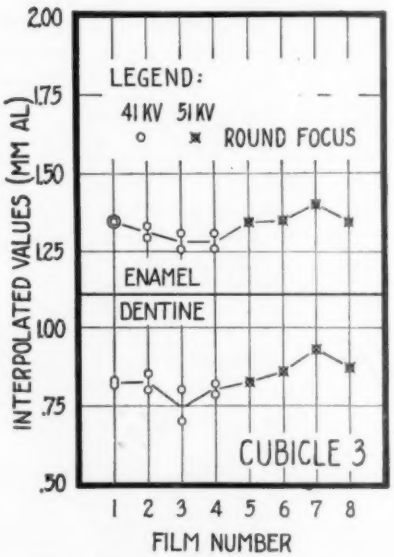


Fig. 127. The I. Vs. for enamel and for dentine are plotted against film number to show reproducibility at 41 and 51 kv. using a round focus tube.

An increase is found of about 0.53 density units with a 9 kv. increase, or $\frac{0.53}{9}$

=0.06 density units per kv. For the line focus tube:

under Step 3 at 53 kv., D. R. = 2.63
at 41 kv., D. R. = 2.35
0.28

under Step 8 at 53 kv., D. R. = 1.92
at 41 kv., D. R. = 1.66
0.26

An increase is found of about 0.28 density units with a 12 kv. increase, or $\frac{0.28}{12}$ =0.02 density units per kv. In cubicle No. 3 using round focus tube:

Table CI

DENSITY UNITS PER KV.

| Tube | Cubicle No. 1 | 2 | 3 |
|---|---|---|---|
| Round focus | 0.06 | 0.06 | 0.09 |
| Line focus | 0.03 | 0.02 | — |

Table CII

R-UNITS MEASURED WITH A VICTOREEN r-METER ON ROUND FOCUS AND LINE FOCUS (AIR-COOLED) TUBES WITH DIFFERENT MACHINES

Exposures at 30 ma., 30 inches, 20 seconds

| | Tube | Kv. (sphere gap) | Filter | Output in r |
|---|---|---|---|---|
| Cubicle No. 1 | Round focus | 48 | None | 17.0 |
| | | 58 | None | 22.5 |
| | $XP_3$, GE | 48 | Built-in | 7.7 |
| | | 58 | Built-in | 9.5 |
| | Machlett line focus | 48 | Built-in | 5.3 |
| | | 48 | Built-in | 7.5 |
| Cubicle No. 2 | Round | 46 | None | 16.4 |
| | | 55 | None | 22.5 |
| | $XP_3$ | 46 | Built-in | 7.0 |
| | | 55 | Built-in | 9.6 |
| | Machlett line focus | 46 | Built-in | 4.5 |
| | | 55 | Built-in | 6.7 |
| Cubicle No. 3 | Round | 48 | None | 11.5 |
| | | 58 | None | 19.0 |
| | $XP_3$ | 48 | Built-in | 5.0 |
| | | 58 | Built-in | 8.5 |
| | Machlett line focus | 48 | Built-in | 3.2 |
| | | 58 | Built-in | 6.3 |

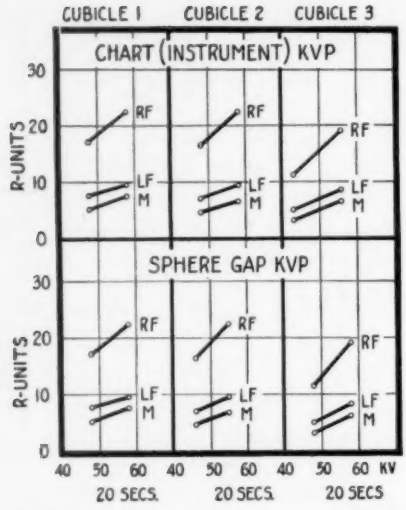


Fig. 128. Output in r is plotted against kv. increase.

under Step 2 at 51 kv., D. R. = 2.44
at 41 kv., D. R. = 1.55
0.89

under Step 8 at 51 kv., D. R. = 1.55
at 41 kv., D. R. = 0.68
0.87

An increase of about 0.89 density units with a 10 kv. increase is found, or $\frac{0.89}{10}$ = 0.09 density units per kv.

To tabulate this information, the density units per kv. for each tube in each cubicle are given below in Table CI. This table presents an indication that it may be possible to characterize tubes and machine-tube combinations photographically with considerable ease and precision. In order to check this suggestion a series of output measurements were made on three tubes, i.e., (1) a round focus Coolidge tube, (2) a line focus XP3 Coolidge tube, and (3) a 200 ma. Machlett tube. Since densities are used in Table CI in checking the differential output of the tubes it seemed a plausible procedure to repeat the general scheme using a Victoreen r-Meter. In Table CII are given the results (data of H. Mermagen) of the tests in which in each of the three cubicles No. 1, 2, and 3, respectively, the three tubes were measured at 48 and 58 (usually) kv., 30 ma., 30 inches, 20 seconds, no tube stand filter. Three identical r-readings were found for each tube-machine combination, at each kv.; only one reading is recorded. In Figure 128 are given graphically (*a*) the relative magnitudes of the output at 48 and at 58 kv. for the three tubes which is shown by the height of the line relative to the base line, and (*b*) the relative increases in r output accompanying a 10 kv. increase, shown by the slope of the lines for each tube. It is apparent that the r output of the tubes is greatest for the round focus, intermediate for the line focus and least for the Machlett tube under the conditions of our experiment. It is also apparent that the round focus tube has a greater increase in r output when the kilovoltage is increased from 48–58 than the other two tubes which are closely similar in increase of r output. The built-in filter is not discussed because it could not be removed practically for these experiments and the tube outputs were compared in accordance with their common usage.

Table CIII

| Ratio | Ratio $\frac{45}{58}$ | Ratio kv. (peak) Sph. gap. | Ratio kv. (peak) Chart |
|---|---|---|---|
| Cubicle No. 1 | | | |
| R. F. | 0.755 | 0.0755 | 0.0755 |
| L. F. | 0.810 | 0.0810 | 0.0810 |
| M. | 0.706 | 0.0706 | 0.0706 |
| Cubicle No. 2 | | | |
| R. F. | 0.729 | 0.081 | 0.0729 |
| L. F. | 0.730 | 0.081 | 0.0730 |
| M. | 0.67 | 0.074 | 0.0670 |
| Cubicle No. 3 | | | |
| R. F. | 0.605 | 0.0605 | 0.046 |
| L. F. | 0.588 | 0.0588 | 0.045 |
| M. | 0.508 | 0.0508 | 0.039 |

In Table CIII the ratios of the r output at 48 and 58 kv. are computed and the

value of this ratio per kv. is shown. The ratios per kv. are plotted against cubicle number in Figure 129, from which it may be seen that the ratio of output is a function of the tube-machine combination and possesses roughly the same relation between tubes as the total outputs (see Fig. 128).

In Table CIV are given differences calculated similarly to those considered in the density calculations above. These values are shown graphically in Figure 130. It may be seen that in cubicle No. 1, the round focus tube increased its r output from 17 to 22.5 when the kilovoltage increased from 48 to 58, or $\frac{5.5}{10}=0.55$ r per kv. The line focus tube increased from 7.7 to 9.5 or $\frac{1.8}{10}=0.18$ r per kv. The Machlett tube increased from 5.3 to 7.5 or $\frac{2.2}{10}=0.22$ r per kv. Similarly in cubicle No. 2, the round focus tube increased 0.68, the line focus 0.29 and the Machlett tube 0.24 r per kv. In cubicle No. 3, the round focus tube increased 0.75, the line focus 0.35 and the Machlett tube 0.31 r per kv. To tabulate these differences and compare them on the basis of the round focus tube, the following data are given in Table CV.

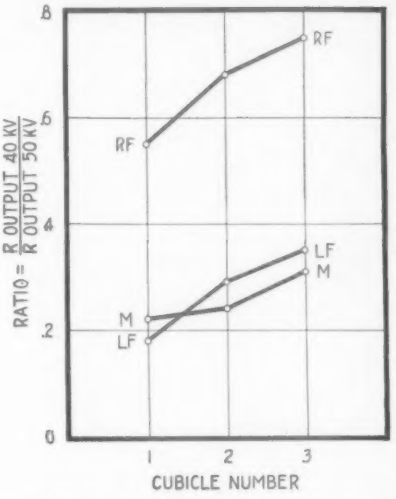


Fig. 130. The increase in output in r per unit increase in kv. is shown to be a function of tube and slightly dependent on the type of rectification.

Table CIV

| Tube | Cubicle No. 1 | Cubicle No. 2 | Cubicle No. 3 |
|---|---|---|---|
| R. F. | $22.5-17=\frac{5.5}{10}=.55$ | $22.5-16.4=\frac{6.1}{9}=.68$ | $19-11.5=\frac{7.5}{10}=.75$ |
| L. F. | $9.5-7.7=\frac{1.8}{10}=.18$ | $9.6-7.0=\frac{2.6}{9}=.29$ | $8.5-5.0=\frac{3.5}{10}=.35$ |
| M | $7.5-5.3=\frac{2.2}{10}=.22$ | $6.7-4.5=\frac{2.2}{9}=.24$ | $6.3-3.2=\frac{3.1}{10}=.31$ |

Table CV

| | r increase per kv. (on basis of round focus tube) | | |
|---|---|---|---|
| Tube | Cubicle No. 1 | No. 2 | No. 3 |
| Round focus | 1.0 | 1.0 | 1.0 |
| Line focus | 0.3 | 0.4 | 0.5 |
| Machlett | 0.4 | 0.4 | 0.4 |

It is evident that the relation between density increase per kv. and the tube output has something more than coincidence behind it, since there is an apparent dependence of the r output per kv. increase and the tube-machine combination, a function apparently more closely dependent on

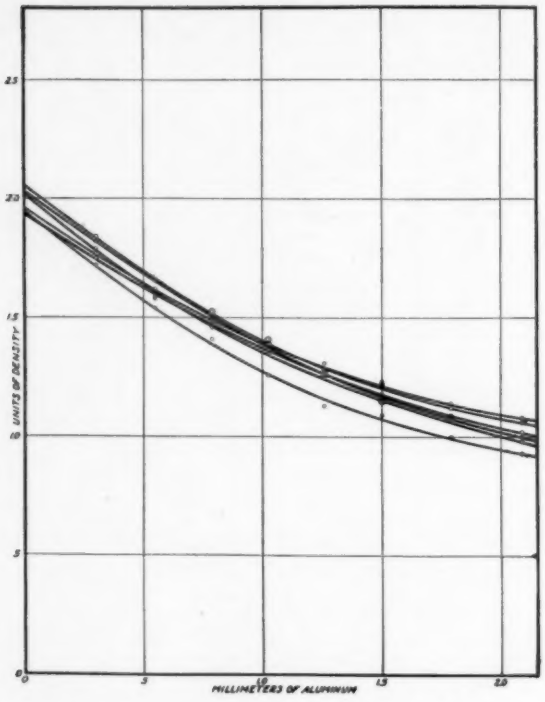


FIG. 131. Six identical exposures using early technique at 51 kv.

the tube than on the type of rectification.

*Summary.* (1) The I. Vs. for enamel and for dentine are independent of the tube-machine combination.

(2) The density increments with kilovoltage increase are functions of tube type and of tube-machine combinations.

### D. TRIPLICATE EXPOSURE REPRODUCIBILITY

Using the early tentative technique, six identical exposures were made at 51 kv., 30 ma., 30 inches and 1 second, without removing the tube stand filter and with the films in the ordinary cardboard cassette. The D. Rs. (Table CVI) in the various steps of the penetrometers are plotted as ordinates against the appropriate thicknesses of the steps (Fig. 131) and the D. Rs. in the enamel and the dentine are interpolated into their equivalent in mm. Al (Table CVI). The D-T curves are of interest principally as regards their slope (compare Fig. 132 in which a 30 kv. tension is used). The variation in I. Vs. (Table CVI) may be roughly estimated as about 20 per cent for both enamel and dentine (Paper II).

With the improved technique which included the wrapping of the films in black paper (see Paper II, B) and the removal of

TABLE CVI

OLD TECHNIQUE, 6 IDENTICAL EXPOSURES, 51 KV. 30 MA., 30 INCHES, 1 SECOND

| Film 931 A Step D. R. | 931 B D. R. | 932 A D. R. | 932 B D. R. | 933 A D. R. | 933 B D. R. |
|---|---|---|---|---|---|
| 1— 1.89 | 1.77 | 2.01 | 1.99 | 1.90 | 1.82 |
| 2— 1.71 | 1.62 | 1.86 | 1.81 | 1.69 | 1.66 |
| 3— 1.58 | 1.49 | 1.72 | 1.68 | 1.57 | 1.55 |
| 4— 1.44 | 1.39 | 1.60 | 1.53 | 1.46 | 1.43 |
| 5— 1.34 | 1.31 | 1.46 | 1.40 | 1.36 | 1.34 |
| 6— 1.27 | 1.23 | 1.34 | 1.36 | 1.26 | 1.25 |
| 7— 1.17 | 1.14 | 1.27 | 1.27 | 1.19 | 1.16 |
| 8— 1.11 | 1.08 | 1.19 | 1.20 | 1.09 | 1.09 |
| Enamel 1.20 | 1.16 | 1.33 | 1.35 | 1.25 | 1.22 |
| Dentine 1.48 | 1.44 | 1.60 | 1.64 | 1.58 | 1.49 |
| Interp. Value (mm. Al) | | | | | |
| En. 1.69 | 1.69 | 1.59 | 1.46 | 1.54 | 1.55 |
| Dent. 0.97 | 0.94 | 1.01 | 0.86 | 0.80 | 0.89 |

TABLE CVII

IMPROVED TECHNIQUE, 6 IDENTICAL EXPOSURES, 51 KV., 30 MA., 30 INCHES, 1 SECOND, BLACK-PAPER-WRAPPED FILM, NO TUBE STAND FILTER

| Film 210 Step D. R. | 220 D. R. | 230 D. R. | 240 D. R. | 250 D. R. | 260 D. R. |
|---|---|---|---|---|---|
| 1— 2.49 | 2.43 | 2.38 | 2.82 | 2.8 | 2.8 |
| 2— 2.23 | 2.16 | 2.08 | 2.45 | 2.54 | 2.45 |
| 3— 2.02 | 1.97 | 1.90 | 2.10 | 2.30 | 2.14 |
| 4— 1.88 | 1.81 | 1.78 | 1.94 | 2.00 | 1.95 |
| 5— 1.72 | 1.69 | 1.65 | 1.75 | 1.85 | 1.82 |
| 6— 1.60 | 1.59 | 1.50 | 1.67 | 1.69 | 1.66 |
| 7— 1.47 | 1.47 | 1.41 | 1.51 | 1.54 | 1.50 |
| 8— 1.42 | 1.37 | 1.36 | 1.38 | 1.42 | 1.41 |
| En. 1.63 | 1.61 | 1.51 | 1.67 | 1.77 | 1.73 |
| Dent. 2.00 | 1.95 | 1.90 | 2.10 | 2.15 | 2.11 |
| Interp. Value (mm. Al) | | | | | |
| En. 1.45 | 1.42 | 1.55 | 1.47 | 1.83 | 1.38 |
| Dent. 0.82 | 0.80 | 0.76 | 0.86 | 0.90 | 0.85 |

the tube stand filter (see Paper II, A) a series of six identical exposures were made at 51 kv., 30 ma., 30 inches, and 1 second. The results obtained shown in Table CVII include the D. Rs. in the various steps of the penetrometers as well as the D. R. in the enamel and in the dentine. The I. V. for enamel range from 1.55 to 1.38 mm. Al, for dentine range from 0.90 to 0.76 mm. Al; a variation roughly estimated as 10–15 per cent. Comparing the D-T curves using the old technique (Fig. 131) with the D T

TABLE CVIII

R. F. D., 10 INDENTICAL EXPOSURES, 51 KV., 30 MA. 30 INCHES, 10 SECONDS, NO TUBE STAND FILTER

| Film 1 A Step D. R. | 1 B D. R. | 2A D. R. | 2B D. R. | 3A D. R. | 3B D. R. | 4A D. R. | 4B D. R. | 5A D. R. | 5B D. R. |
|---|---|---|---|---|---|---|---|---|---|
| 1— 2.38 | 2.20 | 2.32 | 2.24 | 2.32 | 2.17 | 2.28 | 2.23 | 2.34 | 2.22 |
| 2— 2.08 | 1.90 | 2.00 | 1.92 | 1.98 | 1.90 | 1.95 | 1.93 | 2.04 | 1.94 |
| 3— 1.87 | 1.68 | 1.82 | 1.71 | 1.77 | 1.63 | 1.72 | 1.67 | 1.83 | 1.70 |
| 4— 1.68 | 1.49 | 1.63 | 1.52 | 1.59 | 1.46 | 1.60 | 1.43 | 1.65 | 1.54 |
| 5— 1.51 | 1.34 | 1.45 | 1.34 | 1.43 | 1.33 | 1.44 | 1.34 | 1.52 | 1.40 |
| 6— 1.38 | 1.22 | 1.34 | 1.22 | 1.33 | 1.17 | 1.32 | 1.20 | 1.36 | 1.25 |
| 7— 1.26 | 1.10 | 1.22 | 1.08 | 1.19 | 1.09 | 1.24 | 1.07 | 1.23 | 1.11 |
| 8— 1.16 | 0.99 | 1.10 | 0.97 | 1.10 | 0.96 | 1.09 | 0.97 | 1.12 | 0.98 |
| En. 1.43 | 1.22 | 1.37 | 1.24 | 1.35 | 1.21 | 1.34 | 1.22 | 1.39 | 1.30 |
| Dent. 1.84 | 1.64 | 1.80 | 1.69 | 1.78 | 1.67 | 1.78 | 1.68 | 1.84 | 1.70 |
| Interp. Value (mm. Al) | | | | | | | | | |
| En. 1.41 | 1.50 | 1.44 | 1.46 | 1.43 | 1.48 | 1.45 | 1.45 | 1.46 | 1.40 |
| Dent. 0.81 | 0.83 | 0.80 | 0.81 | 0.79 | 0.76 | 0.75 | 0.77 | 0.78 | 0.81 |
| Step 1 (A-B) | .18 | | .08 | | .15 | | .05 | | .12 |

TABLE CIX

FIVE IDENTICAL EXPOSURES, 30 KV., 30 MA., 30 INCHES, 15 SECONDS, NO TUBE STAND FILTER, CARDBOARD CASSETTE

| Step | Film 101 D. R. | Film 102 D. R. | Film 103 D. R. | Film 104 D. R. | Film 105 D. R. |
|---|---|---|---|---|---|
| 1— | 1.25 | 1.31 | 1.30 | 1.28 | 1.30 |
| 2— | 0.86 | 0.87 | 0.87 | 0.86 | 0.89 |
| 3— | 0.60 | 0.63 | 0.61 | 0.60 | 0.63 |
| 4— | 0.46 | 0.46 | 0.48 | 0.48 | 0.46 |
| 5— | 0.37 | 0.36 | 0.37 | 0.37 | 0.37 |
| 6— | 0.28 | 0.30 | 0.32 | 0.32 | 0.31 |
| 7— | 0.25 | 0.26 | 0.27 | 0.25 | 0.27 |
| 8— | 0.22 | 0.22 | 0.24 | 0.25 | 0.23 |
| En. | 0.38 | 0.37 | 0.39 | 0.40 | 0.39 |
| Dent. | 0.62 | 0.62 | 0.61 | 0.61 | 0.63 |
| Interp. Value (mm. Al) | | | | | |
| En. | 1.20 | 1.24 | 1.20 | 1.20 | 1.22 |
| Dent. | 0.71 | 0.73 | 0.75 | 0.76 | 0.73 |

curves (50 kv.) using the new technique (see Paper III, D, Fig. 17) it is observed that the slopes are markedly less at 50 kv. than at 30 kv.

If "radia-tized dental film" is substituted for "dupli-tized x-ray film" and five identical exposures are made, a series of 10 films are obtained (A = upper, B = lower) at 51 kv., 30 ma., 30 inches, and 10 seconds. The D. Rs. in the various steps of the penetrometers are given in Table CVIII; in addition the I. V. for enamel and for dentine are recorded. The D-T curves (not shown) are similar, logarithmic, typical, possessing the same slope as the D-T curves at 50 kv. using "dupli-tized x-ray film." The I. Vs. for enamel range from 1.50 to 1.40 mm. Al, for dentine range from 0.83 to 0.75 mm. Al; values whose variation may be roughly estimated as from 6–10 per cent.

TABLE CX

I. V. (MM. Al) FOR ENAMEL AND FOR DENTINE { 5 I. V. at 5 SEC. / 6 I. V. at 6 sec. } 30 KV. 30 MA., 30 INCHES, NO FILTER CARDBOARD CASSETTES

| Film | I. V. Enamel (mm. Al) | I. V. Dentine (mm. Al) |
|---|---|---|
| 5 seconds | | |
| 101 | 1.20 | 0.71 |
| 102 | 1.24 | 0.73 |
| 103 | 1.20 | 0.75 |
| 104 | 1.20 | 0.76 |
| 105 | 1.22 | 0.73 |
| 6 seconds | | |
| 12 | 1.21 | 0.80 |
| 11 | 1.19 | 0.79 |
| 13 | 1.23 | 0.80 |
| 14 | 1.24 | 0.78 |
| 15 | 1.27 | 0.77 |
| 16 | 1.23 | 0.78 |

All the series of identical exposures so far described have been exposed at 51 kv., the reproducibility of I. V. for enamel and for dentine has been found to be in error by about 10 per cent. By using 30 kv. and all other factors unchanged (as near as possible) the reproducibility of I. V. may be shown to be less than 5 per cent in error (see Paper III).

In Table CIX are given the D. Rs. in the various steps of the penetrometers, in the enamel and in the dentine along with the I. V. in mm. Al for enamel and for dentine in five identical exposures at 30 kv., 30 ma., 30 inches, and 5 seconds. The D-T curves shown in Figure 132 (lower group) are closely grouped, typical. The I. Vs. for

the enamel are given in Table cx as are also the I. Vs. for the dentine. The variation is seen to be not greater than 6 per cent.

In Figure 132 are also shown the D-T curves for six identical exposures at 30 kv., 30 ma, 30 inches, and 6 seconds. The D-T curves at 6 seconds are closely grouped, typical, and of somewhat greater average density for a given thickness of step than the 5-second D-T curves. The I. V. in mm. Al for the enamel and for the dentine are given in Table cx and are taken from Table xxii, Paper iii. The variation is seen to be no greater than 6 per cent.

By wrapping the films in black paper (see Paper ii) and using every precaution to avoid errors, a series of 11 films were taken at 32 kv., 30 ma., 30 inches, and 10 seconds, no tube stand filter, black-paper-wrapped films. The D. Rs. on 3 of the films are given in Table cxi with the D. R. in the enamel and the dentine of tooth No. 1 and 2 along with the I. V. in mm. Al for the enamel and for the dentine. The D-T curves (not shown) are typical. The D. Rs. and I. Vs. for the other 8 films are given in Table xi, Paper ii. In order to scan the I. Vs. from the 11 films for the enamel and for the dentine of teeth No. 1 and 2, the I. Vs. are collected in Table 1, Method Paper (Warren *et al.*). It is seen that the gross variation is less than 5 per cent and the standard deviation represents an error of about 3 per cent.

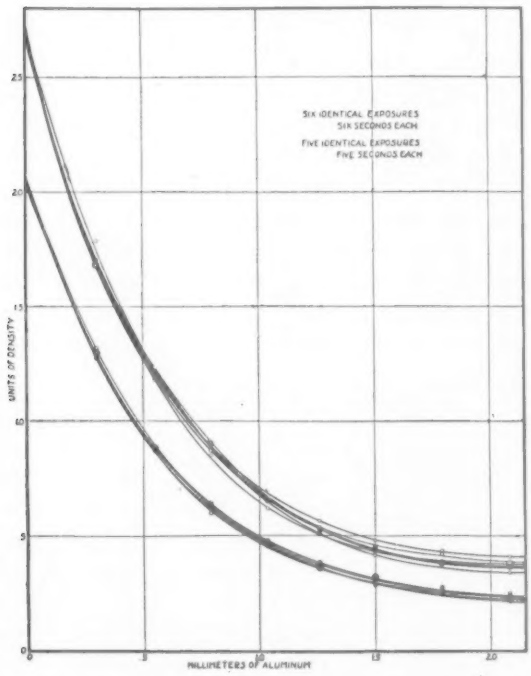


Fig. 132. Six identical exposures at 6 seconds, and five identical exposures at 5 seconds are plotted to show the relative variations in the same tube-machine setup, under as nearly identical conditions as are possible.

Table CXI

THREE IDENTICAL EXPOSURES, 32 KV., 30 MA., 30 INCHES, 10 SECONDS, NO FILTER, BLACK-PAPER-WRAPPED FILMS

| Step | Film 2 (Av.) D. R. | Film 3 D. R. | Film 4 D. R. |
|---|---|---|---|
| 1— | 2.28 | 2.20 | 2.28 |
| 2— | 1.65 | 1.58 | 1.66 |
| 3— | 1.26 | 1.18 | 1.23 |
| 4— | 0.95 | 0.88 | 0.92 |
| 5— | 0.74 | 0.70 | 0.72 |
| 6— | 0.60 | 0.55 | 0.57 |
| 7— | 0.50 | 0.47 | 0.47 |
| 8— | 0.48 | 0.44 | 0.46 |
| Tooth No. 1 | | | |
| En. | 0.73 | 0.67 | 0.70 |
| Dent. | 1.29 | 1.22 | 1.24 |
| Tooth No. 2 | | | |
| En. | 0.74 | 0.65 | 0.67 |
| Dent. | 1.20 | 1.19 | 1.21 |
| I. V. (mm. Al) Tooth No. 1 | | | |
| En. | 1.27 | 1.28 | 1.28 |
| Dent. | 0.76 | 0.76 | 0.79 |
| Tooth No. 2 | | | |
| En. | 1.26 | 1.32 | 1.32 |
| Dent. | 0.80 | 0.78 | 0.81 |

It has been found necessary to stipulate arbitrarily that films be discarded whose density gradient from the left hand side of the thinnest (most dense photographically) step of the left hand penetrometer to the right hand side of the right penetrometer is more than 0.05 density units. By this stipulation the variation calculated from the range of the standard deviation is not

TABLE CXII

30 KV., 30 MA., 15 INCHES, ¾ SECOND, NO FILTER, BLACK-PAPER-WRAPPED FILMS

| Step | Film 9 Densitometer Readings | | Film 10 Densitometer Readings | |
|---|---|---|---|---|
| | Right | Left | Right | Left |
| 1— | 2.15—2.16—2.15 | 2.13—2.15—2.11 | 2.07—2.07—2.06 | 2.07—2.07—2.08 |
| 2— | 1.67—1.66—1.67 | 1.66—1.65—1.64 | 1.58—1.59—1.58 | 1.60—1.61—1.62 |
| 3— | 1.35—1.35—1.36 | 1.36—1.36—1.35 | 1.26—1.24—1.27 | 1.26—1.27—1.27 |
| 4— | 1.13—1.13—1.12 | 1.12—1.12—1.14 | 1.05—1.06—1.05 | 1.05—1.05—1.07 |
| 5— | 0.93—0.93—0.95 | 0.94—0.95—0.97 | 0.84—0.84—0.87 | 0.86—0.85—0.89 |
| 6— | 0.80—0.79—0.83 | 0.81—0.81—0.83 | 0.72—0.70—0.73 | 0.72—0.71—0.74 |
| 7— | 0.68—0.66—0.69 | 0.61—0.62—0.63 | 0.54—0.55—0.58 | 0.56—0.55—0.57 |
| 8— | 0.60—0.60—0.63 | 0.61—0.62—0.63 | 0.54—0.55—0.58 | 0.56—0.55—0.57 |

greater than 5 per cent. In establishing the magnitude of the variation a series of 15 tooth slabs were prepared and exposed in duplicate. The I. Vs. were obtained for one to three areas in the enamel of each tooth, and for five to ten areas in the dentine of each tooth. Then the differences between the I. Vs. for the same area on the duplicate films were calculated and these differences tabulated.

TABLE CXIII

DIFFERENCES BETWEEN I. Vs. FOR THE SAME AREA ON DUPLICATE FILMS

| Enamel | | | Dentine | | |
|---|---|---|---|---|---|
| Difference (Density Units) | No. of Occurrences | | Difference (Density Units) | No. of Occurrences | |
| 0.00 | 6 | | 0.00 | 31 | |
| 0.01 | 10 | | 0.01 | 51 | 132 |
| 0.02 | 4 | 38 | 0.02 | 50 | |
| 0.03 | 12 | | 0.03 | 26 | |
| 0.04 | 6 | | 0.04 | 9 | |
| 0.05 | 2 | | 0.05 | 5 | |
| 0.06 | 3 | | 0.06 | 2 | |
| 0.07 | 3 | | 0.07 | 0 | |
| 0.08 | 2 | | 0.08 | 2 | |
| 0.09 | 1 | | | | |
| 0.10 | 1 | | | | |
| Total | 50 | | Total | 176 | |

By imposing the stipulation that the difference in densitometer reading in the thinnest step between the right hand side of the right penetrometer and the left hand side of the left penetrometer be less than 0.05 density units, a precision unequalled by previous methods is obtained.

Twenty teeth were divided into four equal groups, each group was exposed in duplicate at an exposure of 30 kv., 30 ma., 15 inches, and ¾ second, no tube stand filter, black-paper-wrapped films. D. Rs. were made as usual in the various steps of the penetrometer, any films showing a difference of 0.05 density units in the thinnest step were discarded and the teeth re-exposed. As an example of the constancy of these films, the D. Rs. in two films, 9 and 10, are given in Table CXII. By comparing the D. R. in Step 1 with the D. R. in Step 1 in Table XXX, Paper III, it is apparent why the imposed stipulation increases the precision of the results since a much higher constancy of film density is achieved.

TABLE CXIV

DIFFERENCES IN I. Vs. ON 22 TEETH INVOLVING A TOTAL OF 387 MEASUREMENTS

| Difference in Density Units | Occurrence | |
|---|---|---|
| 0.00 | 52 | |
| 0.01 | 99 | 278 |
| 0.02 | 81 | |
| 0.03 | 46 | |
| 0.04 | 42 | |
| 0.05 | 31 | |
| 0.06 | 21 | |
| 0.07 | 8 | |
| 0.08 | 5 | |
| 0.09 | 2 | |

D. Rs. were made in the tooth slab images of each of the duplicate roentgenograms of each tooth; on the average, two areas in the enamel and nine areas in the dentine of each tooth were measured. By comparing the I. Vs. for the same area from the duplicate films, it is possible to gain an estimate of the precision of the method. The differences between the I. Vs. in the duplicated areas are tabulated for study (Table CXIII). In the enamel, thirty-eight of the fifty tabulated differences are not greater than 0.04 density units, it is easily seen that in 76 per cent of the areas measured the I. Vs. from the two films agreed within $\frac{0.04}{1.4} \times 100$, or 2.8 per cent. In the dentine Table CXIII, 132 of the 176 tabulated differences are not greater than 0.02 density units. Thus $\frac{132}{176}$ or 75 per cent are within 2.5 per cent of numerical agreement.

By taking films in triplicate instead of in duplicate, the possibility of erroneous averages being obtained is considerably decreased. Thus, in order to insure valid results, measurements on all tooth slabs are now being taken in triplicate. In a study of 22 teeth we have read four or five areas in the dentine of each tooth in triplicate. We thus obtained 387 differences (each area read having 3 I. Vs. gives 3 differences). The differences are tabulated (Table CIX) with the number of occurrences of each. The average difference is 0.025 density units; 50 per cent of all the differences lie within 0.0132 of the average; 70 per cent of all the differences lie within 0.0196 of the average. Thus in 70 per cent of the cases, the statistical difference between the I. Vs. for the same spot on any two films is $0.025 \pm 0.0196$, or approximately from 0.0 to 0.045. This corresponds to saying that 70 per cent of the time, the statistical reproducibility of the method is 5 per cent or better. It is of interest to note that of the 387 differences, 278 are within 0.03 of numerical agreement or 72 per cent are within 3.8 per cent, demonstrating that in actual measurements there is better agreement than would be prophesied by statistical calculation.

*Summary.* Using triplicate exposures, and discarding all films in which density gradients greater than 0.05 are found, I. Vs. for enamel and for dentine may be reproduced with an error of less than 5 per cent.

## CONCLUSIONS

1. While the output of a tube changes with the heating of its target, the interpolated values are not influenced thereby.

2. There is an expected and calculable increase of density for a given increase in kilovoltage (10 kv.) but this may be diminished by the built-in filters of modern line focus tubes and the critical angles of their targets. This does not influence the I. Vs. provided the filtration is uniform and the angle of the tube is properly set to give a uniform beam over the film.

3. With uniform conditions, it is possible to reduce the error in obtaining I. Vs. of identical spots in the dentine to less than 4 per cent, using 30 kv., no filter, black-paper-wrapped films, and standard development.

4. All films should be discarded which show a density gradient from one edge of the penetrometer to the other of 0.05 density units.

5. Exposures should be made in triplicate.

# CASE REPORT FROM THE WEEKLY SEMINAR OF THE ROENTGENOLOGICAL DEPARTMENT OF THE MASSACHUSETTS GENERAL HOSPITAL BOSTON, MASSACHUSETTS

*Prepared by* JAMES R. LINGLEY, M.D.

CASE No. 107227. A male, aged thirty-four, postal clerk, entered because of mid abdominal pain of seven months' duration.

FIG. 1. Graham test showing lesion of the second portion of the duodenum outlined by air within it. Only faint shadow of the gallbladder visible.

The pain occurred daily, was dull and throbbing. It radiated from the right upper quadrant to the right iliac crest, lasted several hours, was unrelated to meals and was not relieved by soda. A gastrointestinal series and a Graham test in another hospital were negative, and a bland diet had no effect on the pain. The symptoms became worse during the past two months and he had occasional vomiting. He became constipated and complained of much gas. During the past one and a half months he lost 31 pounds.

Physical examination showed a well-developed and slightly undernourished, somewhat pale man. There was enophthalmus, pupils regular, but left larger than the right. Both reacted well to accommodation, but poorly to light. Abdomen somewhat distended and definitely tender over the whole right side. No masses felt. Red blood cells 3,500,000; white blood cells 13,600, with 7 per cent eosinophils. Four stools were guaiac positive and occult blood was found.

Dr. Hampton will discuss the films which were obtained on gastrointestinal and gallbladder examination.

FIG. 2. Lesion of the second portion of the duodenum completely filled with barium.

## DISCUSSION

DR. HAMPTON: I glanced over the films of this case just before I came over to Seminar and I think that everything that was done was negative with the exception of the stomach and duodenum, isn't that so Dr. Lingley?

DR. LINGLEY: Except the gallbladder examination.

DR. HAMPTON: The gallbladder at this examination was done with the patient having

taken two bottles of the dye and it showed poor concentration but was otherwise normal (Fig. 1). He has a mass of calcified shadows just above the right sacroiliac joint which no doubt shift in position and which probably represent tuberculous glands. The stomach is apparently filled with secretions and food at the time of the examination and it is dilated (Fig. 2). It shows no pressure defects, but does show a fairly small antrum which is probably due to spasm. The duodenum and pyloric valve are distorted and are displaced towards the right and upward. There is a rather sharp angulation of the duodenum and stomach. The duodenum is grossly deformed down to the middle of the third portion (Figs. 3 and 4). I have some difficulty in determining whether this irregular, elongated mass of barium is the second portion of the duodenum, but since it appears to continue with the third portion I assume it to be duodenum (Fig. 4). It is apparently a rigid cavity because on the films of the gallbladder area this portion of the duodenum is filled with air and maintains its abnormal shape (Fig. 1).

A lesion which deforms the entire second portion of the duodenum, perhaps portions of the third and first, and produces complete destruction of the mucosa over an area 6 cm. in length is suggestive of carcinoma. I have seen one patient with seven ulcers in the first and second portion of the duodenum, some of them as much as 2 cm. in diameter, but I never expect to see that again, and this case was due to carcinoma of the ampulla of Vater. There is no indication of a mass here to go with this ulcerated lesion and that is difficult to explain. The stomach is not displaced away from it, neither is the hepatic flexure or colon. In fact the stomach is displaced towards the lesion if anything, so that we must consider an abscess, that is, perforation of the duodenum into an abscess in the region of the pancreas. Where is the second portion of the duodenum? It should be visible if this is a perforated ulcer. Complete ulceration of the small bowel over an area that large without much obstruction, without a mass in the pancreas, with a gallbladder which functions fairly well, I think probably rules out carcinoma of the pancreas or abscess of the pancreas in the region of the ampulla of Vater, because an abscess in that location should obstruct the common duct and prevent any function whatsoever in the gallbladder. I cannot see how a patient could have a lesion this size in the

Fig. 3. Lesion of the second portion of the duodenum partially filled with barium, demonstrating extensive destruction of mucosa.

Fig. 4. Localized film of the diseased area.

second portion of the duodenum without preventing function of the gall bladder. I suspect that the ampulla of Vater, if involved, is completely ulcerated and this allows the common duct to remain open. I am going to conclude that this is an ulcerated tumor of the second portion of the duodenum chiefly on the side of the pancreas but involving about 6 cm. of the duodenum. I do not know of any way to differentiate between carcinoma of the pancreas which extends into the duodenum and primary carcinoma of the duodenum except in the cases where there is a clean cut "napkin ring" deformity which you hope to see in primary carcinoma of the duodenum. I am going to call this primary carcinoma of the duodenum.

DR. LINGLEY: At operation a lesion was found at the junction of the second and third portion of the duodenum, and since a biopsy at that time (frozen section) showed no evidence of malignancy a simple posterior gastroenterostomy was done. Later, sections came back showing malignancy and a second operation was performed, the growth being completely removed. The patient died following this second operation.

DR. HOLMES: How did you rule out lymphoblastoma?

DR. HAMPTON: I think I should have considered it, particularly because of the age of the patient and because of the malignant tumors of the small bowel lymphoma is second in frequency.

DR. HOLMES: I would like to comment a bit on this gallbladder shadow. I have observed that there is impairment of gallbladder function in a large percentage of cases of carcinoma of the head of the pancreas. I think if you could say that it was a normal gallbladder, that would be some evidence against its being a primary tumor of the pancreas. I have seen a number of cases lately with a picture somewhat like this with a faint shadow, the patient having been on a fat-free diet before examination. I think such a filling as this should always make you suspect that the test was not accurate.

DR. SCHATZKI: During fluoroscopy the first striking thing was not what Dr. Hampton just pointed out as probably due to ulceration, but a round defect arising from the greater curvature side of the duodenum at the junction of the second and third portion (Fig. 4). During fluoroscopy I was not absolutely sure whether it was a very tortuous duodenum or a mass projecting into the duodenum. Later, after the films were seen, the ulceration became more obvious. Then it was seen to extend along the inner curvature of the duodenum and it was so large in some places it almost extended over to the outer curvature of the duodenum. Palpation during fluoroscopy showed that there was a ridge protruding into the lumen separating the ulceration from the distal part of the third portion of the duodenum as if there was a ring-like mass surrounding a dish-like ulcer. This made it even more likely that it was a malignant tumor. I thought that the extensive involvement of the duodenum without visible mass in the surroundings made a tumor which originated in the duodenum more likely. At operation the surgeon could not definitely decide whether this was a benign or malignant ulceration. The roentgen findings and location were definitely in favor of malignancy. On the other hand, he did not feel justified in undertaking the risk of resection of the lesion from the adherent head of the pancreas without a positive biopsy report.

DR. HAMPTON: The case to which I referred, the one with seven ulcers, was at first thought not to be malignant, it required many histological studies before carcinoma cells were found. It was finally decided that in this case there was a primary carcinoma of the ampulla of Vater with submucosal metastasis in the duodenum which ulcerated and that is what the case today suggests to me. With a large ulceration and no mass in the bowel I think I will stick to primary carcinoma.

DR. CASTLEMAN: At the first operation the biopsy was pretty small and was composed predominantly of normal pancreas. In paraffin sections, however, we were able to find about 2 mm. of adenocarcinoma. The resected specimen from the second operation, as you see, is composed of a large ulcerated annular tumor mass 6 cm. in diameter, quite characteristic of intestinal cancer. At one end of the tumor within the ulcerated area are the two separate openings of the common bile and pancreatic ducts. Probes into each of these demonstrate their patency. Whether the tumor was primary in the duodenum or in the papilla of Vater cannot be definitely ascertained, but the absence of jaundice at any time certainly favors the former. I personally thought before operation that it might be a leicmyosarcoma, although adenocarcinoma is by far the most common tumor in the small bowel and duodenum. Lymphoma comes next and then sarcoma.

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# EDITORIAL

## THE ETIOLOGY OF PEPTIC ULCER

PEPTIC ulcer is an exceedingly common disease. We have made great advances in our knowledge both of its clinical manifestations and its roentgenological aspects, and while it can be diagnosed with almost a certainty by those trained in roentgenological methods, and the proper mode of treatment is well known, less is known about its etiology.

Recently Babkin,[1] in a thought-provoking paper on the abnormal functioning of the gastric secretory mechanism as a possible factor in the pathogenesis of peptic ulcer, says that, during their study of the physiology of the gastrointestinal tract, he and his coworkers arrived at a new conception of the regulation of the secretory activity of the gastric glands and that it became evident under certain circumstances, owing to some defect in the secretory mechanism, that gastric secretion may deviate from its normal course and conditions may arise which initiate destructive processes in the gastric mucosa. It has long been thought that some defect in the secretory mechanism of the gastric secretion was or might be the cause of peptic ulcer, but the conditions which brought about these disturbances in the secretory mechanism are not clearly understood, and it is apparent that a clear understanding of this mechanism lies at the crux of the whole problem.

Recent physiological investigations give indications that overactivity of the vagus nerve plays a predominant part in the pathogenesis of gastric ulcer. Indeed Manning, Hall and Banting showed that by continuous electrical stimulation of the vagus in the dog they were able to induce gastrointestinal disturbances and produced actual congestion and hemorrhage of the duodenum and pylorus,[2] and Beattie, Watts and Fulton have also demonstrated that damage or stimulation of the hypothalamic region in cats and monkeys is followed by hemorrhage, erosion and even perforation in the stomach and duodenum.[2] Necheles, in his study of the effect of acetylcholine on the circulation of the stomach, showed that small doses of this substance diminished blood flow and thereby produced areas of devitalized tissue.[2] He advanced the theory that acetylcholine liberated in the stomach during the activity of that organ may produce vasoconstriction and therefore may be responsible for the formation of gastric ulcers. Babkin advances the theory that in the normal gastric secretory processes during which histamine is liberated there are possibilities of pathological disturbances which may lead to such grave damage to the gastric or duodenal wall as to produce peptic ulcer. The histamine produces a prolonged stasis in the gastric mucous membrane. The part being deprived of its blood supply becomes devitalized and undergoes necrosis. If the resulting defect in the gastric or intestinal wall affects the mucous membrane only, there is produced an erosion; if an excessive amount of histamine in the tissue be present there may be produced a stasis resulting in infarct with erosion of the mucous membrane, and the destructive process leading to the formation of an ulcer would be completed by the action of the gastric juices on the damaged mucous membrane. He further suggests that the overactivity of the vagus in regions not secreting acid gastric juice, namely the pyloric region and

[1] Babkin, B. P. *Canad. M. Ass. J.*, May, 1938, *38*, 421–429.

[2] *Lancet*, June 18, 1938, *1*, 1400.

[3] *Lancet*, May 14, 1938, *1*, 1122.

[4] *Lancet*, Sept. 18, 1937, *2*, 698.

the initial part of the duodenum, might also be a cause of excessive liberation of histamine with consequent formation of erosions. In these regions the acidity of the gastric contents is still very high and their peptic power has not been greatly diminished by bile and pancreatic juice as it will be when they reach the lower part of the duodenum and jejunum. In consequence, in the former location an erosion of the mucous membrane may be more readily converted into an ulcer. Histamine is normally present in the gastric juice and the source of the histamine equivalent of the gastric juice is presumably the gastric mucosa itself, and Babkin suggests that the secretory fibers of the vagi during activity liberate histamine or histamine-like substances which stimulate the parietal cells, and since histamine has a strong effect on the blood vessels and is able to produce stasis in the capillaries leading to the formation of erosions in the gastric mucosa, in considering the causes of peptic ulcer formation the possible rôle of histamine must not be overlooked.

While the overactivity of the vagus impulses might be the causative factor in the liberation of histamine or histamine-like substances, the mechanism which brings about the vagus stimulation is not clearly understood. It is true that we speak of the "ulcer types" and that duodenal ulcers particularly are apt to occur in the hyperactive, dynamic type of person, but we still are at a loss to explain the various nervous mechanisms which might arise that bring about overstimulation of the vagus nerve in this type of individual. With the advances in our knowledge of the physiology of normal digestion and the nervous mechanisms that play a rôle in this, it is not unlikely that some definite sequence of events will be elaborated to explain some of the discrepancies in our present theories as to the causation of peptic ulcers.

# SOCIETY PROCEEDINGS, CORRESPONDENCE AND NEWS ITEMS

*Items for this section solicited promptly after the events to which they refer.*

## MEETINGS OF ROENTGEN SOCIETIES*

### UNITED STATES OF AMERICA

AMERICAN ROENTGEN RAY SOCIETY
*Secretary*, Dr. C. B. Peirce, University Hospital. Ann Arbor, Mich. Annual Meeting: Atlantic City, N. J., Sept. 20–23, 1938.

AMERICAN COLLEGE OF RADIOLOGY
*Secretary*, Dr. E. L. Jenkinson, 1439 S. Michigan Ave., Chicago, Ill. Annual meeting, 1939: To be announced.

SECTION ON RADIOLOGY, AMERICAN MEDICAL ASSOCIATION
*Secretary*, Dr. J. T. Murphy, 421 Michigan St., Toledo, Ohio. Annual meeting: St. Louis, Mo., 1939.

RADIOLOGICAL SOCIETY OF NORTH AMERICA
*Secretary*, Dr. D. S. Childs, 607 Medical Arts Bldg., Syracuse, N. Y. Annual meeting: Pittsburgh, Pa., Nov. 27–Dec. 2, 1938.

RADIOLOGICAL SECTION, BALTIMORE CITY MEDICAL SOCIETY
*Secretary*, Dr. Howard H. Ashbury, Baltimore. Meets third Tuesday each month, September to May.

RADIOLOGICAL SECTION, CONNECTICUT MEDICAL SOCIETY
*Secretary*, Dr. Max Climan, 242 Trumbull St., Hartford, Conn. Meets twice annually in May and September. Special meetings may be called by the Chairman.

RADIOLOGICAL SECTION, LOS ANGELES CO. MED. SOC.
*Secretary*, Dr. M. L. Pindell, 678 S. Ferris Ave., Los Angeles, Calif. Meets on second Wednesday of each month at County Society Building.

RADIOLOGICAL SECTION, SOUTHERN MEDICAL ASSOCIATION
*Secretary*, Dr. Roy G. Giles, Temple, Texas.

BROOKLYN ROENTGEN RAY SOCIETY
*Secretary*, Dr. E. Mendelson, 120 E. 19th St., Brooklyn, N. Y. Meets monthly on first Tuesday, October to April.

BUFFALO RADIOLOGICAL SOCIETY
*Secretary-Treasurer*, Dr. Joseph S. Gian-Franceschi, 610 Niagara St., Buffalo, N. Y. Meets second Monday of each month except during summer months, place of meeting selected by the host.

CHICAGO ROENTGEN SOCIETY
*Secretary*, Dr. R. G. Willy, 1138 N. Leavitt. Meets second Thursday of each month October to May inclusive at the Palmer House.

CINCINNATI RADIOLOGICAL SOCIETY
*Secretary*, Dr. J. E. McCarthy, 707 Race St., Cincinnati, Ohio. Meets third Tuesday of each month, October to May, inclusive.

CLEVELAND RADIOLOGICAL SOCIETY
*Secretary*, Dr. Harry Hauser, 3395 Scranton Rd. Meetings are held at 6:30 P.M. at the Cleveland Chamber of Commerce Club rooms on the fourth Monday of each month from October to April, inclusive.

DENVER RADIOLOGICAL CLUB
*Secretary*, Dr. E. A. Schmidt, 4200 E. 9th Ave., Denver, Colo. Meets third Tuesday of each month.

DETROIT ROENTGEN RAY AND RADIUM SOCIETY
*Secretary*, Dr. E. R. Witwer, Harper Hospital. Meets monthly on first Thursday from October to May, at Wayne County Medical Society Building.

FLORIDA STATE RADIOLOGICAL SOCIETY
*Secretary*, Dr. J. H. Lucinian, 403 Huntington Bldg., Miami, Florida. Meetings held twice a year, May and November.

GEORGIA RADIOLOGICAL SOCIETY
*Secretary*, Dr. R. C. Pendergrass, Prather Clinic Bldg., Americus, Ga. Meets twice annually: in November and at annual meeting of Medical Association of Georgia in the spring.

ILLINOIS RADIOLOGICAL SOCIETY
*Secretary*, Dr. E. P. Halley, Decatur and Macon County Hospital, Decatur, Ill. Meetings held quarterly, time and place designated by president.

INDIANA ROENTGEN SOCIETY
*Secretary*, Dr. C. C. Taylor, 23 E. Ohio St., Indianapolis, Ind. Meeting held the second Sunday in May annually.

LONG ISLAND RADIOLOGICAL SOCIETY
*Secretary*, Dr. S. G. Schenck, 115 Eastern Parkway, Brooklyn, N. Y. Meets at Kings County Med. Soc. Bldg. on fourth Thursday, each month, October to May, 8:30 P.M.

MICHIGAN ASSOCIATION OF ROENTGENOLOGISTS
*Secretary*, Dr. C. S. Davenport, St. Lawrence Hospital, Lansing. Three meetings a year, Fall, Winter, Spring.

MILWAUKEE ROENTGEN RAY SOCIETY
*Secretary*, Dr. S. A. Morton, Columbia Hospital, Milwaukee, Wis. Meets monthly. Place of meeting named by the president.

MINNESOTA RADIOLOGICAL SOCIETY
*Secretary*, Dr. H. M. Weber, Mayo Clinic, Rochester, Minn.

NEBRASKA RADIOLOGICAL SOCIETY
*Secretary*, Dr. D. A. Dowell, Medical Arts Bldg., Omaha, Nebr. Meets first Wednesday of each month, at 6 P.M., at either Omaha or Lincoln.

NEW ENGLAND ROENTGEN RAY SOCIETY
*Secretary*, Dr. E. C. Vogt, 300 Longwood Ave., Boston, Mass. Meets monthly on third Friday, Boston Medical Library.

RADIOLOGICAL SOCIETY OF NEW JERSEY
*Secretary*, Dr. W. J. Marquis, 198 Clinton Ave, Newark, N. J. Meets annually at time and place of State Medical Society. Mid-year meetings at place designated by the president.

NEW YORK ROENTGEN SOCIETY
*Secretary*, Dr. R. D. Duckworth, 170 Maple Ave., White Plains, N. Y. Meets monthly on third Monday, New York Academy of Medicine, at 8:00 P.M.

NORTH CAROLINA ROENTGEN RAY SOCIETY
*Secretary*, Dr. Major Fleming, Rocky Mount, N. C. Annual meeting at time and place of State Medical Society. Mid-year scientific meeting at place designated.

CENTRAL NEW YORK ROENTGEN RAY SOCIETY
*Secretary*, Dr. C. F. Potter, 820 S. Crouse Ave., Syracuse. Three meetings a year—January, May, November.

PACIFIC ROENTGEN CLUB
*Secretary*, Dr. L. H. Garland, 450 Sutter St., San Francisco, Calif. Meets annually, during meeting of California Medical Association.

PENNSYLVANIA RADIOLOGICAL SOCIETY
*Secretary*, Dr. L. E. Wurster, 416 Pine St., Williamsport, Pa. Annual meeting, May, 1939. Exact time and place to be decided.

PHILADELPHIA ROENTGEN RAY SOCIETY
*Secretary*, Dr. B. R. Young, Temple University Hospital. Meeting first Thursday of each month from October to May inclusive, at 8:15 P.M., in Thompson Hall, College of Physicians, 19 S. 22d St

PITTSBURGH ROENTGEN SOCIETY
*Secretary*, Dr. H. W. Jacox, 4800 Friendship Ave., Meetings held second Wednesday each month, 4:30 P.M., October to June at various hospitals.

ROCHESTER ROENTGEN RAY SOCIETY, ROCHESTER, N. Y.
*Secretary*, Dr. S. C. Davidson, 277 Alexander St., Meets on second Thursday from October to May, inclusive, 8 P.M., Rochester Academy of Medicine Building.

ST. LOUIS SOCIETY OF RADIOLOGISTS
*Secretary*, Dr. W. K. Mueller, University Club Bldg. Meets fourth Wednesday of October, January, March and May, at a place designated by the president.

SAN FRANCISCO RADIOLOGICAL SOCIETY
*Secretary*, Dr. L. H. Garland, 450 Sutter St., San Fran-

*Secretaries of Societies not here listed are requested to send the necessary information to the Editor.

cisco. Meets monthly on first Monday at 7:45 P.M., alternately at Toland Hall and Lane Hall.

South Carolina X-Ray Society
*Secretary*, Dr. R. B. Taft, 105 Rutledge Ave., Charleston. Meets at time and place of South Carolina Medical Assn.

Tennessee Radiological Society
*Secretary*, Dr. F. B. Bogart, 311 Medical Arts Bldg. Chattanooga, Tenn. Meets annually at the time and place of the Tennessee State Medical Association.

Texas Radiological Society
*Secretary*, Dr. G. D. Carlson, 3121 Bryan St., Dallas, Texas. Next regular meeting in San Antonio, Oct. 22, 1938.

University of Michigan Department of Roentgenology Staff Meeting
*Secretary*, Dr. C. B. Peirce, University Hospital, Ann Arbor, Mich. Meets each Monday evening from September to June, at 7 P.M. at University Hospital.

University of Wisconsin Radiological Conference
*Secretary*, Dr. E. A. Pohle, 1300 University Ave., Madison, Wis. Meets every Thursday from 4:00–5:00 P.M., Room 301, Service Memorial Institute.

Virginia Radiological Society
*Secretary*, Dr. V. W. Archer, University Hospital, University, Va. Meets annually in October.

### Cuba

Sociedad Cubana de Radiologia y Fisioterapia
*Secretary*, Dr. Francisco Padron, Enrique, Villuendas 64, Havana, Cuba. Meets monthly in Havana.

### British Empire

British Institute of Radiology Incorporated with the Röntgen Society
Meets on the third Thursday of each month, from November to June inclusive, at 8:15 P.M., at 32 Welbeck St., London, W. 1, or as advertised.

Section of Radiology of the Royal Society of Medicine (Confined to Medical Members)
Meets on the third Friday of each month during the winter at 8:15 P.M. at the Royal Society of Medicine, 1, Wimpole St., London, W. 1.

Section of Radiology and Medical Electricity, Australasian Medical Congress
*Secretary*, Dr. H. M. Cutler, 139 Macquarie St., Sydney, New South Wales.

Radiological Section of the Victorian Branch of the British Medical Association
*Secretary*, Dr. Keith Hallam, St. George's Hospital, K.E.W., Melbourne, E. 4, Victoria, Australia. Meets monthly from March to Nov. incl. for scientific discussion.

Canadian Association of Radiologists
*Secretary*, Dr. A. C. Singleton, Medical Arts Bldg., Toronto, 5, Ontario.

Section of Radiology, Canadian Medical Association
*Secretary*, Dr. C. M. Jones, Inglis St., Ext., Halifax, N.S.

Radiological Section, New Zealand British Medical Association
*Secretary*, Dr. Colin Anderson, Invercargill, New Zealand. Meets annually.

### Continental Europe

Belgian Society of Roentgenology
*Secretary*, Dr. J. Boine, Avenue des Alliés, 134, Louvain (Belgium).
Meets monthly on second Sunday at d'Egmonds Palace, Brussels, except in the summertime.

Sociedad Espanola de Radiologia y Electrologia
*Secretary*, Dr. J. Martin-Crespo, Fuencarral, 7, Madrid, Spain. Meets monthly in Madrid.

Société de Radiologie Médicale de France
Meets monthly on second Tuesday, except during months of August and September, 12 Rue de Seine, Paris.

Société Suisse de Radiologie (Schweizerische Röntgen-Gesellschaft)
*Secretary* for French language, Dr. A. Grosjean, La Chaux de Fonds.
*Secretary* for German language, Dr. Scheurer, Molzgasse, Biel.
Meets annually in different cities.

Société Francaise d'Electrothérapie et de Radiologie Médicale
Meets monthly on fourth Tuesday, except during month of August and September, 12 Rue de Seine, Paris.

Association of German Roentgenologists and Radiologists in Czecho-Slovakia
*Secretary*, Dr. Walter Altschul, German University, Prague, II.52.

Deutsche Röntgen-Gesellschaft (Gesellschaft für Röntgenkunde und Strahlenforschung)
Meets annually in April, alternating one year in Berlin, one year in some other German city. Meets in addition every two years with the Gesellschaft deutscher Naturforscher und Aerzte.
*Permanent Secretary*, Professor Dr. Haenisch, Klopstockstrasse 10, Hamburg, Germany.

Süd- und Westdeutsche Röntgensellschaft
Meets annually in different cities.

Nord- und Ostdeutsche Röntgengesellschaft
Meets annually in different cities.

Dutch Society of Electrology and Roentgenology
Holds two meetings a year in Amsterdam, one in the Spring, and one in the fall.

Societa Italiana Radiologia Medica
*Secretary*, M. Ponzio, University of Turin, Prof. Turin.

Societatea Romana de Radiologie si Electrologie
*Secretary*, Dr. Oscar Meller, Str. Banul Mărăcine, 30, S. I., Bucuresti, Roumania.
Meets second Monday in every month with the exception of July and August.

All-Russian Roentgen Ray Association, Leningrad, USSR in the State Institute of Roentgenology and Radiology, 6 Roentgen St.
*Secretaries*, Drs. S. A. Reinberg and S. G. Simonson, Meets annually.

Leningrad Roentgen Ray Society
*Secretaries*, Drs. S. G. Simonson and G. A. Gusterin.
Meets monthly, first Monday at 8 o'clock State Institute of Roentgenology and Radiology, Leningrad.

Moscow Roentgen Ray Society
*Secretaries*, Drs. L. L. Holst, A. W. Ssamygin and S. T. Konobejevsky.
Meets monthly on the first Monday at 8 o'clock, the place of meeting being selected by the Society.

Polish Society of Radiology
*Secretary*, Dr. Jan Kochanowski, 45 Gornoslazka St., Warsaw. Meets annually.

Warsaw Section, Polish Society of Radiology
*Secretary*, Dr. B. Krynski, 11 Zielna St.
Meets once a month except in the summertime.

Scandinavian Roentgen Societies
The Scandinavian roentgen societies have formed a joint association called the Northern Association for Medical Radiology, meeting every second year in the different countries belonging to the Association. Each of the following societies, with exception of the Denmark Society, meets every second month except in the summertime:

Society of Medical Radiology in Sweden
Meets in Stockholm.

Society of Medical Radiology in Norway
Meets in Oslo.

Society of Medical Radiology in Denmark
*Secretary*, Dr. G. Biering, Copenhagen.
Meets the second Wednesday of each month from October to July in Copenhagen, at 8 o'clock in the State Institute of Roentgenology.

Society of Medical Radiology in Finland
Meets in Helsingfors.

Vienna Roentgen Society
Meets first Wednesday of each month, at 6:30 P.M. at Zentral-Röntgen Institut des allgemeinen Krankenhauses Alserstrasse 4.

### Orient

Japan X-Ray Association
c/o Orthopedic Surgery, Tokyo Imperial University. Meets annually in April.

Kinki Roentgen-Abend Society
Director, Dr. Prof. Taiga Saito, Ogawaoike Tyoto Japan. Meets bi-monthly on third Sunday.

# INTERNATIONAL RECOMMENDATIONS FOR X-RAY AND RADIUM PROTECTION

## REVISED BY THE INTERNATIONAL X-RAY AND RADIUM PROTECTION COMMITTEE AT THE FIFTH INTERNATIONAL CONGRESS OF RADIOLOGY, CHICAGO, SEPTEMBER 13–17, 1937

### INTERNATIONAL RECOMMENDATIONS

1. The dangers of overexposure to x-rays and radium can be avoided by the provision of adequate protection and suitable working conditions. It is the duty of those in charge of x-ray and radium departments to ensure such conditions for their personnel. The known effects to be guarded against are:

(a) Injuries to the superficial tissues.

(b) Changes in the blood and derangements of internal organs, particularly the generative organs.

The evidence at present available appears to suggest that under satisfactory working conditions, a person in normal health can tolerate exposure to x-rays or radium gamma rays to an extent of about 0.2 international roentgen (r) per day or 1 r per week. On the basis of continuous irradiation during a working day of seven hours, this figure corresponds to a tolerance dosage rate of $10^{-5}$ r per second. The protective values given in these recommendations are generally in harmony with this figure under average conditions.

### I. WORKING HOURS, ETC.

2. The following working hours, etc., are recommended for whole-time x-ray and radium workers:

(a) Not more than seven working hours a day in temperate or cold climates. For workers in tropical climates shorter hours may be desirable.

(b) Not more than five working days a week. The off-days to be spent as much as possible out of doors.

(c) Not less than four weeks' holiday a year, preferably consecutively.

(d) Whole-time workers in hospital x-ray and radium departments should not be called upon for other hospital service.

(e) X-ray, and particularly radium workers, should be systematically submitted, both on entry and subsequently at least twice a year, to expert medical, general and blood examinations, special attention being paid to the hands. These examinations will determine the acceptance, refusal, limitation or termination of such occupation.

(f) The amount of radiation received by operators should be systematically checked to ensure that the tolerance dose is not exceeded. For this purpose, photographic films or small-capacity condensers may be carried on the person.

### II. GENERAL X-RAY AND RADIUM RECOMMENDATIONS

3. X-ray departments should not be situated below ground floor level.

4. All rooms, including dark rooms, should be provided with windows affording good natural lighting and ready facilities for admitting sunshine and fresh air whenever possible.

5. All rooms should be provided with adequate exhaust ventilation. In certain climates it may be necessary to have recourse to air conditioning. For rooms of normal dimensions, say 3,000 cubic feet (90 c. meters) in which corona-free apparatus is installed, the ventilating system should be capable of renewing the air of the room not less than six times per hour, while up to ten times may be required when the apparatus is not corona free. Large rooms require proportionately fewer changes of air per hour than small ones. Air inlets and

outlets should be arranged to afford crosswise ventilation of the room.

6. All rooms should preferably be decorated in light colors.

7. A working temperature of about 18°–22°C. (65°–72°F.) is desirable in x-ray rooms.

8. X-ray rooms should be large enough to permit a convenient lay-out of the equipment. A minimum floor area of 250 sq. ft. (25 sq. meters) is recommended for x-ray rooms, and 100 sq. ft. (10 sq. meters) for dark rooms. Ceilings should be not less than 11 ft. (3.5 meters) high.

9. High-tension generators employing mechanical rectification should preferably be placed in a separate room from the x-ray tube.

### III. X-RAY PROTECTIVE RECOMMENDATIONS

10. An x-ray operator should on no account expose himself to a direct beam of x-rays.

11. An operator should place himself as remote as practicable from the x-ray tube. It should be borne in mind that valve tubes are capable of producing x-rays.

12. The x-ray tube should be self-protected, or otherwise surrounded as completely as possible with protective material of adequate lead equivalent.[1]

13. The following lead equivalents are recommended under average conditions:

| X-rays generated by peak voltages | Minimum equivalent thickness of lead |
|---|---|
| Not exceeding 75 kv. | 1.0 mm. |
| 100 | 1.5 |
| 125 | 2.0 |
| 150 | 2.5 |
| 175 | 3.0 |
| 200 | 4.0 |
| 250 | 6.0 |
| 300 | 9.0 |
| 350 | 12.0 |
| 400 | 15.0 |
| (600) | (35.0) |

[1] The lead equivalent of a given thickness of protective material is that thickness of lead which is equally opaque to x-rays excited at some specified peak voltage.

*(A) Diagnostic Work*

14. In the case of diagnostic work with other than completely protected tubes, the operator should be afforded additional protection from stray radiation by a screen of a minimum lead equivalent of 1 millimeter.

15. Screening examinations should be conducted as rapidly as possible with minimum intensities and apertures, particularly when fractures are reduced under x-rays. Palpation with the hand should be reduced to the minimum.

16. The lead glass of fluorescent screens should have the protective values recommended in paragraph 13.

17. In the case of screening stands, the fluorescent screen should, if necessary, be provided with a protective "surround," so that adequate protection against direct radiation is afforded for all positions of the screen and diaphragm.

18. Screening stands and couches should provide adequate arrangements for protecting the operator against scattered radiation from the patient.

19. Protective gloves, which should be suitably lined with fabric or other material, should have a protective value not less than $\frac{1}{3}$ millimeter lead throughout both back and front (including fingers and wrist). Protective aprons should have a minimum lead value of $\frac{1}{2}$ millimeter.

*(B) Treatment*

20. In the case of x-ray treatment, the operator is best stationed completely outside the x-ray room behind a protective wall, the lead equivalent of which will depend on the circumstances. In the case of a single x-ray tube excited by voltages up to 200 kv., the protective wall should have a minimum lead equivalent of 2 millimeters. This figure should be increased in the case of higher exciting voltages or of heavy tube currents or if the protective value of the x-ray tube enclosure falls short of the value given in paragraph 13. In such event the remaining walls, floor and ceiling may also be required to provide supplementary protection for adjacent occupants

to an extent depending on the circumstances. Full protection should be provided in all those directions in which the direct beam can operate.

Inspection windows in screens and walls should have protective lead values equivalent to that of the surrounding screen or wall.

21. In those cases in which an x-ray tube is continuously excited and treatment periods are regulated by means of a shutter, some form of remote control should be provided for the shutter, to ensure that the operator is not exposed to direct radiation while manipulating the shutter or filter.

22. Efficient safeguards should be adopted to avoid the omission of a metal filter in x-ray treatment, for example, by an interlocking device or by continuously measuring the emergent radiation. Protective screens and applicators (cones) used in treatment to define the ports of entry of x-ray beams should be sufficiently thick to reduce the dosage rate outside the direct field of irradiation to less than $10^{-3}$ roentgen per second.

### IV. ELECTRICAL PRECAUTIONS IN X-RAY ROOMS

23. The floor-covering of the x-ray rooms should be insulating material such as wood, rubber or linoleum.

24. Where permanent overhead conductors are employed, they should be not less than 9 feet (3 meters) from the floor. They should consist of stout metal tubing or other coronaless type of conductor. The associated connecting leads should be of coronaless wire kept taut by suitable rheophores.

25. Wherever possible, earthed guards or earthed sheaths should be provided to shield the more adjacent parts of the high-tension system. Unshielded leads to the x-ray tube should be in positions as remote as possible from the operator and the patient. The use of "shock-proof" x-ray equipment, in which the high-tension circuit is completely enclosed in earthed conductors, is recommended. In all cases however, indiscriminate handling of x-ray tubes during operation should be forbidden. Unless there are reasons to the contrary, metal parts of the apparatus and room should be efficiently earthed.

26. Main and supply switches should be very accessible and distinctly indicated. They should not be in the proximity of the high-tension system, nor should it be possible for them to close accidentally. The use of quick-acting, double-pole circuit breakers is recommended. Over-powered fuses should not be used. If more than one apparatus is operated from a common generator, suitable high-tension, multi-way switches should be provided. In the case of some of the constant potential generators, a residual charge is held by the condensers after shutting down, and a suitable discharging device should therefore be fitted. Illuminated warning devices which operate when the equipment is "alive" serve a useful purpose. The staff should be trained in the use of first-aid instructions dealing with electrical shock. If foot switches are used, they should be connected in series with an ordinary switch, and should be so designed that they cannot be locked to keep the circuit "alive," and are not capable of being closed accidentally.

27. Some suitable form of kilovoltmeter should be provided to afford a measure of the voltage operating the x-ray tube.

28. Low flash-point anesthetics should never be used in conjunction with x-rays.

### V. FILM STORAGE PRECAUTIONS

29. The use of non-inflammable x-ray films is strongly recommended. In the case of inflammable films, suitable precautions should be taken as regards their use and storage. Large stocks should be kept in isolated stores, preferably in a separate building or on the roof.

### VI. RADIUM PROTECTIVE RECOMMENDATIONS

#### (*A*) *Radium Salts*

30. Protection for radium workers is required from the effects of:

(a) Beta rays upon the hands.
(b) Gamma rays upon the internal organs, vascular and reproductive systems.

31. In order to protect the hands from beta rays, reliance should be placed, in the first place, on distance. The radium should be manipulated with long-handled forceps, and should be carried from place to place in long-handled boxes, lined on all sides with at least 1 centimeter of lead. All manipulations should be carried out as rapidly as possible.

32. Radium, when not in use, should be stored in a safe as distant as possible from the personnel. It is recommended that the safe should be provided with a number of separate drawers individually protected. The amount of protection should correspond to the values given in the following table. These values, which are based on working conditions where there is proximity to radium, may be reduced for larger working distances.

| Maximum quantity of radium element | Thickness of lead |
|---|---|
| 0.05 gm. | 5.0 cm. |
| 0.2 | 8.5 |
| 0.5 | 10.0 |
| 1.0 | 11.5 |
| 2.0 | 13.0 |
| 5.0 | 15.0 |
| 10.0 | 17.0 |

33. A separate room should be provided for the "make-up" of screened tubes and applicators, and this room should only be occupied during such work.

34. In order to protect the body from the penetrating gamma rays during handling of radium, a screen of not less than 2.5 centimeters of lead should be used, and proximity to the radium should only occur during actual work, and for as short a time as possible.

35. The measurement room should be a separate room, and it should preferably contain the radium only during its actual measurement.

36. Nurses and attendants should not remain in the same room as patients undergoing radium treatment with quantities exceeding 0.5 gram.

37. All unskilled work, or work which can be learned in a short period of time, should preferably be carried out by temporary workers, who should be engaged on such work for periods not exceeding six months. This applies especially to nurses and those engaged in "making up" applicators.

38. Radium containers should be tested periodically for leakage of radon. Prejudicial quantities of radon may otherwise accumulate in radium safes, etc., containing a number of leaky containers.

39. Discretion should be exercised in transmitting radium salts by post. In the case of small quantities (less than 10 mg. of radium element) it is recommended that the container should be lined throughout with lead not less than 3 millimeters thick while for quantities between 10 and 50 mg. of radium element, the lead container should be supported in the center of a box with a minimum dimension of 30 cm. Packages containing more than 50 mg. of radium element are preferably sent by rail or hand under suitable conditions of protection.

*(B) Radon*

40. In the manipulation of radon, protection against beta and gamma rays is required, and automatic or remote controls are desirable.

41. The handling of radon should be carried out, as far as possible, during its relatively inactive state.

42. Precautions should be taken against excessive gas pressures in radon plants. The escape of radon should be very carefully guarded against, and the room in which it is prepared should be provided with an exhaust fan controlled from outside the room.

43. Where radon is likely to come in direct contact with the fingers, thin rubber gloves should be worn to avoid contamination of the hands with active deposit.

Otherwise, the protective measures recommended for radium salts should be carried out.

44. The pumping room should preferably be contained in a separate building. The room should be provided with a connecting tube from the special room in which the radium is stored in solution. The radium in solution should be heavily screened to protect persons working in adjacent rooms. This is preferably done by placing the radium solution in a lead-lined box, the thickness of lead recommended being according to the table in paragraph 32.

*(C) Radium-Beam Therapy*

45. The risks to the operator attendant on the use of large quantities of radium in radium-beam therapy may be largely obviated if some system of remote control is adopted by which the radium is only introduced into the "bomb" after the latter has been adjusted in position on the patient. If such arrangements are not available the importance of expeditious handling is stressed.

46. Rooms used for radium-beam therapy should provide adequate protection for adjacent wards and rooms in permanent occupation.

The following minimum lead thicknesses are required to secure a tolerance dosage rate of $10^{-5}$ roentgen per second at various distances from different quantities of radium.

The distances corresponding to the tolerance dosage rate in the absence of lead are also given.

| Quantity or radium element (0.5 mm. Pt screen) | Thickness of lead to give tolerance dosage rate at the following distances from radium source | | | | Tolerance distance with no lead |
|---|---|---|---|---|---|
| | 50 cm. | 1 meter | 2 meters | 5 meters | |
| gm. | cm. | cm. | cm. | cm. | meters |
| 1 | 9.0 | 6.0 | 3.0 | — | 4.5 |
| 2 | 10.5 | 7.5 | 4.5 | 1.0 | 6.5 |
| 5 | 12.5 | 9.5 | 6.5 | 2.5 | 10.5 |
| 10 | 14.0 | 11.0 | 8.0 | 4.0 | 14.5 |

Members of Committee Making Above Report

G. W. C. Kaye,
(Great Britain) *Hon. Secretary*
H. Behnken, Germany
E. Pugno-Vanoni, Italy
I. Solomon, France
Lauriston S. Taylor, U. S. A.

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## PRELIMINARY PROGRAM OF THE FOURTH MIDSUMMER RADIOLOGICAL CONFERENCE IN THE ROCKY MOUNTAINS, DENVER

Sponsored by the Denver Radiological Club August 11, 12, 13, 1938. All Meetings held in the Hotel Shirley-Savoy, Colorado Room.

### Thursday Afternoon, August 11

12:00 to 2:00 P.M. Registration.

2:00 P.M. John S. Bouslog, M.D., Presiding. President, Denver Radiological Club.

2:00 P.M. Address of Welcome, W. T. H. Baker, M.D., President, Colorado State Medical Society, Pueblo.

2:15 P.M. "The Diagnosis of Thoracic Diseases Other Than Tuberculosis," Wendell G Scott, M.D., Saint Louis.

3:00 P.M. "The Classification, Recognition and Differentiation of Bone Tumors" Lowell S. Goin, M.D., F.A.C.R., Los Angeles.

4:00 P.M. "Irradiation Therapy of Bone Tumors" Orville Meland, M.D., F.A.C.S., Los Angeles.

4:45 P.M. Discussion by Ralph E. Herendeen, M.D., New York City.

5:00 P.M Adjournment.

### Thursday Evening, August 11

8:00 P.M. Joint meeting with the Medical Society of the City and County of Denver, W. W. Haggart, M.D., Presiding. President of the Medical Society of the City and County of Denver.

Guest Speakers:

Samuel B. Childs Lecture: B. R. Kirklin, M.D., F.A.C.R., Rochester, Minnesota, "Clinical Indications for Roentgenologic Examination of the Gastrointestinal Tract."

Sanford Withers Lecture:

Subject to be announced later, Ralph E. Herendeen, M.D., New York City.

Friday Morning, August 12

9:00 A.M. "The Roentgenological Aspect of Collapse Therapy in Pulmonary Disease," Ernst A. Schmidt, M.D., Denver.

9:20 A.M. "The Joint Changes in Hemophilia," Nathan B. Newcomer, M.D., Denver.

9:40 A.M. "Fractures and Pseudo-Fractures of the Sutures of the Skull," Frank B. Stephenson, M.D., Denver.

10:00 A.M. "Pulmonary Infarcts", Lowell S. Goin, M.D., Los Angeles.

10:45 A.M. "The Radiological Diagnosis of Heart Disease with Special Reference to Roentgen Kymography," Wendell G. Scott, M.D., Saint Louis.

11:30 A.M. "Roentgenologic Study of the Stomach and Duodenum Following Operation," B. R. Kirklin, M.D., F.A.C.R., Rochester, Minnesota.

12:15 P.M. Adjournment.

12:30 P.M. Luncheon.

Friday Afternoon, August 12

1:00 to 2:30 P.M. Round Table Discussion of the Problems of Diagnostic Radiology, H. P. Brandenburg, M.D., Denver, Presiding.

2:30 P.M. "Arthritis," Kenneth D. A. Allen, M.D., Denver.

3:00 P.M. "Errors in the Diagnosis of Spondylolisthesis," W. W. Wasson, M.D., Joseph Connell, M.D., and G. E. Sanford, M.D., Denver.

3:30 P.M. "Diaphragmatic Hernia," Leonard G. Crosby, M.D., Denver.

4:00 P.M. "Quality of Roentgen Ray: Physical Aspects," R. R. Newell, M.D., San Francisco.

4.30 P.M. Discussion.

5:00 P.M. Adjournment.

Friday Evening, August 12

6:30 P.M. Social Hour.

7:15 P.M. Informal Banquet, John S. Bouslog, M.D., Presiding, President, Denver Radiological Club.

Saturday Morning, August 13

9:00 A.M. "Advances in Radiation Therapy," Paul R. Weeks, M.D., Denver.

9:30 A.M. "Irradiation Therapy in the Treatment of Mixed Cell Tumor of the Parotid," Edward J. Meister, M.D., Denver.

10:00 A.M. "The Treatment of Carcinoma of the Breast: Technic, Complications and Results," Elizabeth Newcomer, M.D., Denver.

10:30 A.M. "Quality of Roentgen Ray: Clinical Importance," R. R. Newell, M.D., San Francisco.

11:00 A.M. Supject to be announced later, Ralph E. Herendeen, M.D., New York City.

11:45 A.M. "How Can the Results of Irradiation in Carcinoma of the Rectum Be Improved Upon?" Orville N. Meland, M.D., F.A.C.S., Los Angeles.

12:15 P.M. Adjournment.

12:30 P.M. Luncheon.

Saturday Afternoon, August 13

1:00 to 2:30 P.M. Round Table Discussion of Therapeutic Radiology, George Unfug, M.D., Pueblo, Presiding.

## FLORIDA RADIOLOGICAL SOCIETY

The Florida Radiological Society, at its recent annual meeting at Miami, elected the following officers for the ensuing year: *President:* Harold O. Brown, M.D., Tampa; *Vice-President:* Harry B. McEuen, M.D., Jacksonville; *Secretary-Treasurer:* Joseph H. Lucinian, M.D., Miami. Meetings are held twice a year, in May and November.

## INDIANA ROENTGEN SOCIETY

The annual meeting of the Indiana Roentgen Society was held in Indianapolis on May 15, 1938. Dr. Karl Kornblum of Philadelphia was a guest of the Society and talked at the after-dinner session on "Roentgenology of the Urinary Tract." The following officers were elected: *President:* Stanley A. Clark, M.D., South Bend; *President-Elect:* Juan Rodriguez, M.D., Fort Wayne; *Vice-President:* A. C. Holley,

M.D., Attica; *Secretary-Treasurer:* Clifford C. Taylor, M.D., Indianapolis.

## NEW YORK ROENTGEN SOCIETY

At the one hundred and eighty-third regular meeting of the New York Roentgen Society held at the New York Academy of Medicine on May 16, 1938, the following officers were elected: *President:* Raymond W. Lewis, M.D.; *Vice-President:* Henry K. Taylor, M.D.; *Secretary:* Roy D. Duckworth, M.D.; *Treasurer:* Eric J. Ryan, M.D.; *Member of the Executive Committee:* E. Forrest Merrill, M.D.

## PITTSBURGH ROENTGEN SOCIETY

At a recent meeting of the Pittsburgh Roentgen Society the following officers were elected: *President:* William B. Ray, M.D., *Secretary:* Harold W. Jacox, M.D. Meetings are held the second Wednesday of each month at 4:30 P.M. from October to June at various hospitals designated by the Program Committee.

## RADIOLOGICAL SOCIETY OF NEW JERSEY

At the meeting of the Radiological Society of New Jersey held in Atlantic City in conjunction with the annual meeting of the Medical Society of New Jersey, May 17 to 19, 1938, the following officers were elected for the coming year: *President:* M. Friedman, M.D.; *Vice-President:* P. S. Avery, M.D.; *Secretary:* W. James Marquis, M.D.; *Treasurer:* James Boyes, M.D.; *Counsellor:* H. A. Vogel, M.D.

## A CORRECTION

In the article by Robert S. Stone and Fritz J. Schulze on "Ventricular Changes Caused by Proved Tumors of the Brain," April, 1938, number of the JOURNAL, the sentence at the top of page 526 reading "It was noted that the septum pellucidum was displaced more toward the side containing the tumor than was the third ventricle in 8 of the 12 patients with lesions of the frontal lobe" should be corrected to read "It was noted that the septum pellucidum was displaced more toward the side *not* containing the tumor . . . ."

# BOOK REVIEWS

*Books sent for review are acknowledged under: Books Received. This must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interests of our readers as space permits.*

THE RÔLE OF CHEMIOTAXIS IN BONE GROWTH. By A. P. Bertwistle, M.B., Ch.B., F.R.C.S. (Edin.). Cloth. Price 8/6. Pp. 59, with 32 illustrations. London: Henry Kimpton, 1937.

In this small volume of 59 pages, the author promulgates a law, based on histological grounds, which through the use of disruptive chemiotaxis, a new process to Medicine, covers the whole field of bone pathology. He states this law as follows: "That whenever young fibrous tissue, particularly young blood-vessels, come into contact with bone or a calcified deposit, new bone formation occurs." Failure to appreciate this fact has led, he believes, to much misunderstanding in bone pathology. It explains periosteal regeneration of bone, a much discussed subject.

The first chapter is devoted to disruptive chemiotaxis. Chemiotaxis is defined as the power of attraction which certain substances, notably the products of bacterial activity, have for leukocytes; the leukocytes are urged to them and finally ingest the bacteria. Disruptive chemiotaxis is a term coined to express the power of certain hard substances of attracting and drawing into themselves certain soft living structures. It is a tremendous power in plant life and thus is a great help in studying the same phenomenon in bone. The root of the plant pierces the relatively hard ground because it is drawn downward by an extremely strong attraction—chemiotaxis. The effect of this process in plant life is discussed in detail.

The second chapter consists of an account of normal bone development, and is a free translation of Bouin's description of the histology and development of bone in his volume, "Elements d'histologie."

In Chapter III, disruptive chemiotaxis and its relationship to calcification and ossification in normal bone are discussed. Just as in the case of a plant's roots which manifest an urge to travel towards water, so in bone, calcium exerts a power of attraction over the blood-vessels in its neighborhood. Wherever a deposit of calcium appears, it is promptly followed by bone. In the ossification of the primary center and the epiphysis and in the demolition of bone, the process is taking place. The vital phenomena which take place in the development of bone are described in detail and from these the author deduces the above mentioned law which he considers of such great importance in bone pathology.

In the fourth chapter periosteal bone is discussed. All expansions of bone are brought about by periosteal new osseous formation. The simplest view to take of the periosteum is that it is a fibrous tissue, which reacts to the stimulus of bone or calcified deposit, including dead bone, in exactly the same manner as any other fibrous tissue. It is exquisitely sensitive to changes in tension. Examples of such changes are described in pyogenic osteomyelitis, syphilis, tuberculosis, typhoid fever, osteitis deformans, periosteal and endosteal sarcoma and other conditions.

Bertwistle believes that the phenomenon of disruptive chemiotaxis and the application of the law of development of bone, wherever young fibrous tissue comes in contact with a calcified deposit of bone, is nowhere seen to better advantage than in the study of fractures and bone grafts. This subject furnishes the material for the fifth chapter. In the sixth chapter the law is applied to the changes found in myositis ossificans and other ectopic bone formation.

Roentgenograms are employed to illustrate periosteal expansion, new bone formation and other changes in the various disease processes. The importance of their use in elucidation of problems in bone pathology and diagnosis is emphasized. Whether or not the reader may agree with the opinions and theories set forth in this small monograph it is well worth study by all physicians interested in the development and pathological conditions of bone.

R. S. BROMER

THE TREATMENT OF CLINICAL AND LABORATORY DATA: AN INTRODUCTION TO STATISTICAL IDEAS AND METHODS FOR MEDICAL AND DENTAL WORKERS. By Donald Mainland, M.B., Ch.B., D.Sc. (Edin.), Professor of Anatomy, Dalhousie University, Halifax,

Nova Scotia, Canada. Cloth. Price, 15/. Pp. 340, with 23 text figures. Edinburgh: Oliver and Boyd, 1938.

The steeply ascending curve of publications in the physical, chemical and biological fields may offer pleasant satisfaction to the printing fraternity, but to the confused and weary consumer, it is something less than an unmitigated blessing. In moments of pessimism, one may be excused for toying with the idea of founding a "Society of the Suppression of Unnecessary Publication." And there is further justification for this not-so-fantastic notion in the fact that the quality of the published material is often very low indeed. Particularly is this true of the treatment accorded by authors to the arrays of their observational data.

This sort of defect, a source of amusement or anguish to the professional statistician, is often quite apparent to the thoughtful general reader who pauses to wonder why, for example, a writer reporting the results of an investigation has ignored the elementary limitations of the numerical data, namely, the experimental error and reliability of interpretations from restricted numbers of observations. The reader may also marvel at editorial machinery that accepts and purveys such stuff and worse.

This irritating and unfortunate situation is of course not confined to the clinical field, but few will dispute the allegation that it contributes more than its due share. There is no easy way to deal with the problem. The primary responsibility rests with the investigator, no doubt, but after such material is submitted for publication in a journal, the editors thereof can hardly evade their share in it. In this connection, there is no need to add to the overworked theme of the variability of biological material, except to recall that its undue emphasis may be largely a matter of ignorance and evasion.

In the book under review, Professor Mainland (an anatomist, by the way) seeks to do his bit toward advancing elementary statistical literacy. It is "an attempt, primarily, to show why and how allowance should be made for chance, so that a clinician may get the most sound benefit (a) from his own observations, and (b) from the observations of others." There are various excellent texts on statistical methods, but these are usually too difficult or forbidding for clinical workers. The present work is not an exhaustive treatise. It attempts instead "to show the *reasonableness* of methods and formulae, rather than their exact mathematical *reasons*." Examples drawn from the literature are used to illustrate the general principles and technique of counting and measurement, the study of averages and of variation, and the detection of how one measurement or number varies when others vary. The presentation is directed largely toward the needs of the beginner. There is rather frequent repetition throughout the book, but this, the author feels, is a desirable feature. Dr. Mainland writes well and interestingly, and it is to be hoped that his conscientious effort will be rewarded by continued improvement of standards in the field to which he has addressed himself.

Barnett Cohen

La hernie postérieure du ménisque intervertébral (hernie nucléaire postérieure) es ses complications nerveuses. Par Pierre Glorieux, Bruges. Paper. Price, 40 fr. Pp. 102, with 98 illustrations. Paris: Masson & Cie, 1937.

This timely monograph on posterior herniation of the intervertebral disc in 25 cases is extremely interesting since the subject will probably be of increasing importance in the study of cases of back pain and post-traumatic syndromes. If a comparison be made with the cases reported in this country, one is impressed with the fact that the present group shows a larger number following trauma. In addition multiple lesions are relatively more common.

Glorieux states that posterior nuclear herniation should be thought of under the following conditions:

I. Traumatic cases.

A. In trauma to the spine without a demonstrable bone lesion but in which neurologic signs appear, either radicular, medullary or both, immediately after the trauma or following several weeks of freedom from symptoms. A narrowed disc space is frequently but not always found.
B. In spine fractures occurring through flexion or extension but with contraction of the opposing muscles. Either a bony fragment of the posterior surface of the vertebra is projected into the spinal canal (which is pathognomonic) or a neurologic syndrome is found.
C. Radicular symptoms occurring fol-

lowing a spine fracture due to flexion or extension with contraction of the opposing muscles.

II. Non-traumatic cases.

A. Patients presenting progressive static pain especially with recurring lumbago.

B. Patients with a neurologic syndrome in which roentgenologically there are small bony formations on the posterior aspect of a disc. Stereoroentgenograms made from various angles are necessary because localized ossifications of the ligamentum flavum may be mistaken for ossification of a posterior hernia.

C. Patients presenting a slowly progressive neurologic syndrome of compression, radicular, medullary or both. In some cases, simple roentgenograms show a narrowed disc but its absence does not exclude a hernia. This is probably the condition in a large number of cases of so-called essential sciatica which do not respond to the usual treatment. The author calls attention to the importance of the reverse Queckenstedt test and to the exaggeration of pain induced by epidural injection as described by Love.

D. All patients presenting a syndrome suggesting possible compression the origin of which is not clear. It was curious and unexplained that most cases showed left peripheral neurologic signs: right localization was rare.

Myelography is essential to establish the diagnosis. In the cauda equina region with the patient in the prone position the lipiodol passes usually in front of the roots, rarely between or more rarely, behind. In the anteroposterior position, the lipiodol column has a spindle appearance in the first and third methods of passage. If a nuclear herniation is present, the spindle is hollowed out on one or both sides. With the patient prone, in the lateral view, the column is also spindle shaped but not as wide; the lipiodol is in almost immediate contact with the posterior face of the vertebra, more rarely with the lamina. In the presence of hernia, the spindle may also be hollowed out from in front but not necessarily. If the patient lies on the side of the hernia, there may be an unevenness of the opaque column as a whole.

In the region of the spinal cord, the lipiodol passes either in front of the cord or in the lateral gutters in front of the dentate ligaments. If it passes in front of the cord, the column will be deviated to right or left if the hernia is lateral. If median, the classic picture of an antemedullary tumor is obtained. If the lipiodol passes down the lateral gutters, a unilateral hernia will obstruct one side. If bilateral, it will obstruct both sides to a greater or lesser extent, the lipiodol breaking up into droplets. A possible source of error in the lower cervical region is commented on, since there is tendency for lipiodol to collect in a pool caused by the cervical lordosis.

The author concludes that the demonstration of one or many nuclear hernias does not establish a cause and effect relationship. This can only be determined by a correlation of clinical and roentgenologic data.

Chapters on prognosis, with special reference to the medicolegal aspects, and on treatment are given. The indications for operative procedure are entirely clinical. The operation of choice is laminectomy, excision of the tumor and an Albee graft. However, the author has found that, particularly in the lumbar region, decompression alone without excision may be sufficient.

The monograph is well written, easily read and liberally illustrated by clear reproductions.

Marcy L. Sussman

Methodik der Röntgenuntersuchung des Kehlkopfes. (*Fortschr. a. d. Geb. d. Röntgenstrahlen*, Ergänzungsband 53.) Von Dr. Richard Waldapfel, Assistent der Ohren-, Nasen-, Halsabteilung der allgemeinen Poliklinik in Wien. Paper, price M. 17.60; bound, M. 19.60. Pp. 90, with 77 illustrations. Leipzig: Georg Thieme, 1938.

The possibilities offered by the roentgen examination in the diagnosis of disorders of the larynx are admirably presented in this study. The author is described as an assistant in the Ear, Nose and Throat Department of the Vienna Allgemeinen Poliklinik. Thus his interests are not purely roentgenological and his material is presented with the closest attention to the clinical and practical aspects.

In addition to the standard lateral or transverse projection using soft rays with the patient in a sitting position and the film placed against the neck on the affected side, the author makes use of an anteroposterior view in which the film, enclosed in a suitable holder, is inserted into the upper esophagus. This is accomplished

under local anesthesia and, with a little practice, can be carried out very simply and with no discomfort to the patient. In many instances it yields valuable additional information.

One chapter is given to a description of the ossification in the laryngeal cartilages and the variations in the roentgen appearance with age and sex. A familiarity with the usual appearance of the ossifications as well as of the normal anatomy of the soft tissues of the neck in both anteroposterior and lateral projections is necessary for a proper orientation and recognition of abnormalities.

The pathology of the larynx is described according to the primary involvement of different structures. Both views are necessary to a proper study of the region of the epiglottis. Cases are described and illustrated where there was more or less extensive neoplastic involvement of the epiglottis together with the changes which occurred following therapy. The roentgen appearance of injuries to the thyroid cartilage, of unusual appearances of the arytenoid cartilages, and of acute perichondritis of the cricoid cartilage, together with the possibilities of demonstrating the crico-arytenoid joint are presented in great detail. The author's experience does not permit him to state the ultimate clinical importance of a demonstration of the crico-arytenoid joint, but it illustrates the type of anatomical detail which can be studied in this manner. The greatest interest lies in the pathology of the soft tissues of the larynx. Numerous case histories are given where the laryngoscopic examination failed to give satisfactory or complete evidence of the underlying process and where recognition of the true state of affairs came from the roentgen examination. It is emphasized that the laryngoscopic examination gives only a view of the superior surfaces whereas the roentgen examination gives the downward extent of the process and sometimes evidence of the nature of the process itself. Such instances are illustrated by a case of pneumatocele of the false vocal cord, carcinomas of the under surface of the true vocal cords, and examples of tuberculous and syphilitic inflammations. Tuberculous infections are often associated with a characteristic dull appearance of the cartilages which lack the normal sharply defined areas of ossification. A simultaneous destruction and regeneration of cartilage and bone gives a coarse granulated appearance which is not seen in syphilis or tuberculosis and indicates a neoplastic process. A number of cases of laryngeal stenosis are presented with illustrations showing how the roentgen examination gives the character and extent of the involvement.

Normally the posterior portion of the larynx lies in close approximation to the posterior wall of the pharynx. There is, however, a potential space between them called the hypopharynx, and this sometimes demands special investigation. It can be well shown in the lateral view by making the exposure with a sound in the larynx upon which sufficient pressure is exerted to displace the larynx anteriorly. This simple procedure is sometimes helpful in distinguishing whether small shadows in this region are foreign bodies or areas of cartilage ossification. The latter will move forward, maintaining a constant relationship to the other cartilages as the larynx is displaced anteriorly, while the foreign body will remain fixed or change its position relative to the laryngeal structures. However, as Jackson has emphasized, 98 per cent of the foreign bodies in this region lodge below the inferior margin of the cricoid cartilage and a shadow in this area then is almost certainly a foreign body.

In conclusion, the author emphasizes that no one procedure is sufficient for the diagnosis of diseases of the larynx, but that all means must be employed and carefully coördinated. The roentgen examination is particularly helpful in determining (1) the margins and downward extent of laryngeal processes, (2) narrowing of the air space with the site and extent of the stenosis, and (3) the posterior and anterior extension of processes, and (4) induration and destruction of the laryngeal cartilages.

William A. Evans, Jr.

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# ABSTRACTS OF ROENTGEN AND RADIUM LITERATURE

## ROENTGEN DIAGNOSIS

### HEAD

SCHOUR, I., and PONCHER, HENRY G. Rate of apposition of enamel and dentin, measured by the effect of acute fluorosis. *Am. J. Dis. Child.*, Oct., 1937, *54*, 757–776.

*Authors' summary and conclusions:*

The effects of injection of small doses of sodium fluoride on growing teeth were studied in a hydrocephalic infant between the ages of five and nine months. The dose varied from 1 to 2 cc. of 2.5 per cent solution. The medical history and the observations made at autopsy showed no general toxic effects of fluorosis. A histologic analysis yielded the following observations:

1. The dentin showed a stripe of disturbed calcification and the enamel showed a stripe of disturbed growth and calcification in the portion of the tissue which had been forming and calcifying at the time of each injection.

2. The average rate of apposition of the dentin in the root of the deciduous upper central incisor, based on 1,100 measurements of the distance between successive injection lines, was 3.77 microns per twenty-four hours.

3. The average rate of apposition of the enamel in the gingival portion of the deciduous lower second molar, based on 165 measurements, was 3.92 microns per twenty-four hours.

4. The average rate of apposition of the enamel of the permanent teeth present, based on 1,360 measurements, was 2.71 microns per twenty-four hours.

5. Slight but consistent deviations from the average rate of apposition were observed; they appeared to correspond with the particular form and contour of a given tooth. These deviations are indicative of a definite gradient of growth for each type of tooth.

6. In the deciduous teeth, a distinct ring of disturbed calcification was found in the enamel and the dentin which were formed at and soon after birth. These rings are regarded as the neonatal rings in the enamel and the dentin and constitute a landmark which separates the prenatal portions of the deciduous teeth. The histologic analosis indicated better prenatal than postnatal colcification.

The authors present an experimental method wherebo further light may be thrown on a number of phases of the normal processes of formation and calcification of the teeth. They hope that similar collaborative studies will be conducted.—*R. S. Bromer.*

NEWMAN, HENRY. Encephalography with ethylene. *J. Am. M. Ass.*, Feb. 6, 1937, *108*, 461–463.

Any modification of technique that will serve to lessen the unpleasantness of encephalography will be effective in increasing its scope of usefulness. The author's aim has been to maintain a relatively constant spinal fluid pressure rather than to attempt a volume for volume replacement. Eight encephalographies were done with nitrous oxide, but it was found that this gas was absorbed too rapidly for good roentgenologic results. A change was then made to ethylene, and since then 30 encephalographies have been done with this agent. Roentgenograms must be made immediately after the injection because of the fairly prompt disappearance of subarachnoid ethylene. Aird, in 1934, had reported the use of anesthetic gases experimentally in dogs, and found a definite anesthetic or analgesic effect with ethylene. The author could not confirm this in humans. However, after the injection most of the patients were quite comfortable within three or four hours, and in almost every instance able to be up and about the following day. That this shorter period of recovery from headache is due to the more rapid absorption of ethylene seems most probable. It is believed that the solubility of the gas and not its anesthetic properties is responsible for its advantage over air.

Serial roentgen studies after the injection of ethylene showed the subarachnoid gas to disappear within a very short time. The ventricular gas was half gone within three hours, but some small residue could be seen even twenty-four hours later. Cell counts on the spinal fluid indicate that ethylene possesses no more irritating qualities than does air.

The ready solubility of ethylene raises the possibility of its being absorbed more rapidly than fluid could be formed to take its place, with resulting production of a negative cerebrospinal fluid pressure. Investigation revealed a marked drop in pressure following the injection, a negative value of 13 cm. of water being reached at the end of an hour. At two hours the pressure had attained zero, and subsequently rose to normal values. That such a marked change in pressure may be undesirable from the standpoint of the safety of the patient must be borne in mind, but in this series it has not been productive of serious sequelae.—*S. G. Henderson.*

NECK AND CHEST

Gershon-Cohen, Jacob, and Colcher, A. E. An evaluation of the roentgen diagnosis of early carcinoma of the breast. *J. Am. M. Ass.*, March 13, 1937, *108*, 867–871.

The diagnosis of an early malignant growth by roentgen examination must first take into consideration the point at which "early malignancy" is to be placed. If malignancy were regarded in most instances as simply a later stage in the evolution of neoplasia, the beginning of which is always benign, like tumors of the type classified as adenoma, fibro-adenoma and papilloma, the problem would be relatively simple.

The paper is based on the study of 41 patients, the sections of the amputated breasts of these patients all being examined by an expert pathologist. The percentage of correct preoperative roentgen interpretations was higher than that made by the pathologist when limited to his macroscopic studies, but lower than that made after his histologic studies. Any tumor that is palpable can be demonstrated in the roentgenogram. The authors made their most frequent errors in the diagnosis of mammary malignant growths in breasts if examined at the time of their greatest physiologic activity. One of the essential criteria for malignant infiltration is the presence of an invading peripheral margin. Some element of speculation will generally be present in a diagnosis based on a single roentgen study of an adult breast, still active in a woman during the premenopausal years. Radiation therapy appears to the authors as one method offering some diagnostic aid.

The least number of errors in the roentgen diagnosis of malignant mammary tumors was made in the atrophic breasts, usually at or after the menopause. Some slow-growing tumors show a tendency to remain localized, enlarging slowly by gradual peripheral accretion of new cells, creating a smooth surface, and leading to an erroneous roentgen impression of benignancy. The multinodularity often ascribed to a breast is not commonly due to the unevenness of the surface of the gland itself but to isolated lobules of fat separated from one another by dense subcutaneous projections of the suspensory ligaments of Cooper. Deep-seated nodules are found more easily by the roentgen examination than by palpation. By careful attention to a study of the margins a successful differential diagnosis has been made between solid and cystic tumors. A cystic tumor has a sharp, smooth and almost perfect circular margin, while a solid tumor practically never has a perfect circular margin but always some eccentric bulge due to lobulation or some flattening or interaction of its periphery due to fibrosis.

A remarkably high percentage of roentgen diagnoses is proved to be correct by histologic studies, and this can be increased if the examination is more seriously and uniformly emphasized. Early malignancy can be very frequently determined especially in the fat and postclimacteric breast. If periodic examinations of normal breasts were carried out in women past twenty-five years of age, a much more effective campaign could be therapeutically waged in carcinoma of the mammary gland because of the diagnosis of early malignancy so obtainable.—*S. G. Henderson.*

Hicken, N. Frederick, Best, R. Russell, Moon, Charles F., and Harris, T. Tennyson. The preoperative visualization of breast tumors. *J. Am. M. Ass.*, March 13, 1937, *108*, 864–867.

Tumors of the breast can be visualized *in situ* by contrast roentgenographic studies, using such contrast mediums as stabilized thorium dioxide sol, lipoiodine and air. When using radiopaque substances the resulting roentgenograms are known as mammograms. If air is used as a contrast agent, this type of study is known as aeromammography. The technique is simple. The milk duct is cannulized with a blunt No. 25 gauge needle and is then injected with 1 cc. of stabilized thorium

dioxide sol. The resulting roentgenogram outlines the course of the milk duct. Lesions appear as filling defects.

Papillomatous tumors are often multiple and may arise in any segment of the lactiferous ducts. A simple excision of one tumor may not be curative, for similar growths may be developing in other portions of the same breast. Papillomas may simultaneously involve the two breasts. These neoplasms may have a certain constitutional or endocrinological background. The clinical value of mammographic studies in the diagnosis of breast neoplasms is emphasized.

Insufflations of air are valuable in facilitating the diagnosis of breast tumors, particularly lipomas, fibro-adenomas, simple retention cysts and carcinomas. However, aeromammograms do not visualize small papillomas, early carcinomas, small retention cysts or cystic dilatation of the milk ducts. In order to visualize such tumors, the lactiferous ducts must be injected with some contrast medium. The combination of the ductal injection and the insufflation of air is ideal, for it permits a complete visualization of all the structures of the breast.—*S. G. Henderson.*

Brailey, Miriam. Mortality in tuberculin-positive infants. *Bull. Johns Hopkins Hosp.*, July, 1936, *59*, 1–10.

Brailey, Miriam. Factors influencing the course of tuberculous infection in young children. *Am. Rev. Tuberc.*, Sept., 1937, *36*, 347–354.

The patients forming the basis for this study were 223 infants observed to have a positive tuberculin test within the first two years of life. The mortality was found to be highest in the early months of observation and to fall as the observation period became longer. The mortality at all periods was over twice as great in the colored children. For the five-year period it was 10 per cent for the white, and 22 per cent for the colored patients. The five-year mortality was 30 per cent for those showing a definite parenchymal lesion, 13 per cent for those with enlarged tracheobronchial lymph glands, and 9 per cent for those with normal chests on roentgen examination. In the last two groups deaths occurred only in colored patients. When the parenchymal lesion was such as to give signs on physical examination, the five-year mortality was 82 per cent. The mortality was found to be higher, the younger the patient when the infection first became evident. In patients dying with a parenchymal lesion, death is most often due to extrapulmonary causes such as tuberculous meningitis or generalized tuberculosis.—*W. A. Evans, Jr.*

Brailey, Miriam. Observations on the development of intrathoracic calcification in tuberculin-positive infants. *Bull. Johns Hopkins Hosp.*, Oct., 1937, *61*, 258–271.

These studies are particularly interesting because of the long period during which the infants were observed and the completeness with which the studies were made during the observation period. They were carried out in the Harriet Lane Tuberculosis Clinic of the Johns Hopkins Hospital under the direction of Dr. E. A. Park. The subjects were both white and colored, under two years of age and without evidence of calcification when first seen. All had positive Mantoux tests. Definite calcification within the chest developed in the first year in 17 per cent of the infants under observation, 47 per cent by the end of the second year, 62 per cent in the third, and 66 per cent after the fourth and fifth years. There was no significant racial difference in the rate or incidence of calcification. Calcification occurred in over 80 per cent of children who survived a definite parenchymal lesion. The incidence was lower in those with less extensive lesions being only 35 per cent in those where no lesion has been demonstrable. Irrespective of the location of the active lesion, calcium was deposited first and most frequently in the nodes at the hilum. The right side of the chest was involved much more frequently than in the left. The calcification is most easily recognizable a few months after it appears. Later the deposits become rounded, lose their characteristic appearance so that they may be mistaken for blood vessels in cross section, or disappear behind the sternum. In 5 of 70 cases the deposits of calcium which were very distinct at one time could not be demonstrated at a later date. In one case there was apparently absorption of a large calcium deposit in the parenchyma of the lung, four years after it was first seen. In only one or two of the cases was a diminution in the allergic response to old tuberculin noted during the observation period.—*W. A. Evans, Jr.*

Beck, C. S. Acute and chronic compression of the heart. *Am. Heart J.*, Nov., 1937, *14*, 515–525.

The compressed heart is a small quiet organ. It is embarrassed because it cannot dilate and receive an optimum quantity of blood and it may undergo an atrophy of disuse. The valves are normal, and there are no murmurs. As the compression develops the amplitude of the cardiac pulsation becomes more limited. The roentgen examination is important to determine this point and to determine the nature of the compressing agent whether fluid, scar tissue, or tumor.

The pressure of the bloood in the venae cavae is normally at atmospheric or less than atmospheric pressure. In acute cardiac compression when blood or exudate accumulates in the pericardium, there is produced a pressure greater than that in the veins and thus flow of blood into the heart is prevented. To overcome increased pericardial pressure, the venous pressure cannot rise to a greater height than 15 or 20 cm. hydrostatic pressure.

Experimentally it was found that the heart could tolerate a higher degree of compression if the compression developed slowly. A higher systemic venous pressure is possible in the chronic condition because of a greater blood volume. The clinical manifestations of chronic compression of the heart are attributable to venous congestion and reduced arterial circulation. The fact that the heart is small distinguishes this condition from the more common congestive heart failure where the heart is enlarged. Pericardial adhesions alone play no part in the compression syndrome and do not produce circulatory embarrassment. Some of the chronic compressions are due to infections, followed by the formation and contracture of the scar. Most of the infections were believed to be pyogenic; about 10 per cent were tuberculous. Other causes of chronic compresson are slow hemorrhage, tumors, and mediastinal effusions. The condition is often amenable to surgical treatment.—*W. A. Evans, Jr.*

Berner, F. Ein neues Röntgensymptom bei Herzbeutelerguss. (A new roentgen sign in pericardial effusion.) *Fortschr. a. d. Geb. d. Röntgenstrahlen*, Oct., 1937, *56*, 536–540.

This sign consists in the kymographic demonstration of a relatively large pulsation on the left border of the aortic shadow with a pulsation of small amplitude on the left border of the heart. The sign is not applicable when there is disease of the aorta, when there has been an old pericarditis which obscures the pulsation at the left border of the heart, or in massive pericardial effusions where the shadows of the great vessels are obscured. The author states that the usual signs of pericardial effusion are not reliable and that the differential diagnosis of pericardial effusion and myocarditis is a difficult one. A diminished amplitude of pulsation is common to both conditions. The changes in the conformation of the kymographic waves which Stumpf described in pericardial effusion are not characteristic of that condition alone. The author formulated his sign of pericardial effusion from theoretical considerations and presents one case in which it was applicable.—*W. A. Evans, Jr.*

Dry, T. J. An approach to the diagnosis of congenital heart disease. *Am. Heart J.*, Aug., 1937, *14*, 135–154.

The possibilities of making an accurate diagnosis of congenital heart disease and the importance of such a diagnosis are becoming more recognized. The author reviews the developmental anatomy of the heart under (1) septal formations dividing the heart into right and left chambers, (2) torsion of the cardiac tube, (3) development of the bulbus cordis, (4) incorporation of the sinus venosus into the right auricle, (5) the evolution of the aortic arches, (6) closure of fetal channels after birth, and shows how disturbances in these processes are related to the common congenital anomalies. Clinical findings which lead one to suspect congenital cardiac disease are bruits and thrills, which are not explainable on the basis of the common acquired valvular lesions and particularly if they have been present from early infancy; evidences of a venous-arterial shunt such as cyanosis, clubbed fingers, and polycythemia; an unusual contour of the heart on the roentgenogram, most commonly a prominence of the pulmonary artery, but also shadows to the right of the sternum extending toward the right sternoclavicular joint indicating a persistent right aortic arch; hypertension, particularly when it occurs without apparent cause in the young patient, may indicate coarctation of the aorta; congenital anomalies elsewhere in the body; and subacute bacterial endocarditis. The electrocardiogram may offer

helpful contributory evidence of congenital heart lesions. The diagnostic criteria are described for the common anomalies—interventricular septal defect (maladie de Roger), interauricular septal defect (patent foramen ovale), Lutembacher's disease, mitral stenosis and interauricular septal defect, subaortic, and subpulmonic stenosis, tetralogy of Fallot, patent ductus arteriosus, coarctation of the aorta (often diagnosed roentgenographically from the scalloping of the ribs caused by the collateral circulation), persistent right aortic arch, best demonstrated roentgenographically by the shadow to the right of the manubrium sterni and by the displacement of the trachea and esophagus toward the left often sufficient to cause dysphagia (dysphagia lusoria). The prognosis in congenital heart disease is determined by the nature of the mechanical difficulties which the lesion produces and also by the susceptibility of such lesions to rheumatic fever and subacute bacterial endocarditis. Even extensive abnormalities may be compatible with a long active life.—*W. A. Evans, Jr.*

CRAMER, H., and STEHR, L. Ergebnisse der Kymographie bei Herzbeutelaffektionen. (Results of kymography in diseases of the pericardium.) *Fortschr. a. d. Geb. d. Röntgenstrahlen*, Sept., 1937, *56*, 404–418.

The pericardium is the least important of the three layers of the heart (both physiologically and anatomically). In a healthy state it can rarely be demonstrated with the roentgen ray; occasionally a portion is seen between the heart and the diaphragm on deep inspiration and occasionally the pericardial fat pad may be seen overlying the left ventricle. The most common form of pericarditis, the fibrinous variety, is not demonstrable with the roentgen ray. Stumpf observed the disappearance of the finer movements of the heart border in large pericardial effusions. A circumscribed pericardial obliteration may give an area without movement on the kymogram which must be differentiated from a myocardial infarction. This is simplified if calcification can be demonstrated in the pericardium. Calcification of the pericardium, even when very extensive, is an incidental finding and not in itself productive of symptoms. A constrictive pericarditis may obstruct the opening of the vena cava producing the syndrome of Pick's cirrhosis. The form of the heart is not altered in this condition but calcification may be demonstrated in the pericardium and this is helpful in the diagnosis. Calcification was found to begin in the region of the coronary arteries. When there is very extensive calcification of the pericardium there is not a disappearance of the kymographic pulsations as one might expect for the pericardium can be shown to be made up of fine calcium particles held together by connective tissue and which therefore is flexible. Indeed, with extensive calcification there may be an increased amplitude in the left ventricular area and this is to be explained by the fixation of the right border and anterior surface of the heart by dense adhesions to the sternum leaving only the left border relatively free for movement.—*W. A. Evans, Jr.*

BERG, GUNNAR, and ZIMMERMANN, GERDA. Unsere Erfahrungen mit dem Verfahren des Röntgenschichtbildes auf dem Gebiet der Lungendiagnostik. (Our experiences with the technique of roentgen planigraphy in the field of pulmonary diagnosis.) *Fortschr. a. d. Geb. d. Röntgenstrahlen*, Oct., 1937, *56*, 530–535.

According to these authors, the first patents on a roentgen technique to show an isolated layer in some part of the body appeared in France in 1921 (Bocage, Portes, Chauce) and the first German work was published by Pohl in 1937. The material reported is based on studies of 100 patients at the medical clinic in Heidelberg. The authors recommend that a roentgen examination with the usual technique be carried out preliminary to this special study. The most important indications for planigraphy in the study of the lungs are: (1) the demonstration of doubtful cavities in the apical fields, behind the clavicle, in the hilar areas, behind thickened pleura, or pleural effusions, and in dense parenchymal infiltrations, and (2) the localization of pleural adhesions in treatment by pneumothorax. The technique has also proved helpful in studies on patients with marked curvatures of the spine. A group of 6 cases is presented with illustrations showing findings which could be demonstrated by planigraphy, but were doubtful or not demonstrable at all on the usual film.—*W. A. Evans, Jr.*

MCGEACHY, T. E., and PAULLIN, J. E. Dissecting aneurysm of the aorta. *J. Am. M. Ass.*, May 15, 1937, *108*, 1690–1698.

There have been almost 500 cases dealing with rupture of the aorta reported in the literature, and in only 9 instances has a correct ante-mortem diagnosis been made. The authors report 3 cases in which a correct ante-mortem diagnosis was made, bringing the total number to twelve.

Dissecting aneurysm of the aorta is an incomplete rupture of the aortic wall wherein the escaping fluid separates the layers of the arterial wall to a variable extent. Dissecting aneurysm is most common between the ages of forty and seventy years. Males are affected twice as frequently as females. Predisposing factors are a defective aortic wall and an abnormal hydrostatic pressure in the aorta. It seems clear that the real causative factor lies in the media. The only fairly constant finding in the media has been a degenerative change, which results from sclerosis of the vasa vasorum. Hypertension is generally a factor in cases of dissecting aneurysm. The onset is marked by a sudden, agonizing, tearing pain, usually in the anterior portion of the chest, followed immediately by shock, the pain lasting usually from ten minutes to two or three hours. The pain often radiates to the back or to the epigastrium. The blood pressure is usually found above normal, in spite of other signs of shock. Coolness and absence of arterial pulsation in one or more extremities are frequently present and are the most outstanding diagnostic signs. Blockage of a carotid artery gives the neurologic picture of a widespread cerebral hemorrhage or embolism. In a considerable majority of patients there is a stage, following the onset and preceding the terminal collapse, in which the patient is fairly comfortable. The physical signs found at the onset remain fairly constant, such as murmurs over the heart and arteries, elevated blood pressure, cardiac enlargement and increase in mediastinal dullness. This stage may last for a period of minutes to several years but is usually a matter of days. Terminal collapse is sudden, and is evidence of rupture through the outer coat of the aorta.

Laboratory studies usually show a distinct leukocytosis ranging from 9,000 to 30,000, with a relative polymorphonuclear increase. Left axis deviation and changes in the T-waves have been the most constantly observed features in electrocardiographic studies. Roentgenographic features as observed by Wood, Pendergrass and Ostrum include usually a deformity of the supracardiac shadow, which may or may not pulsate under the fluoroscope, at times a shadow seen along an aortic branch which is the most pathognomonic of all roentgen appearances, at times a displacement of the trachea and esophagus and nearly always cardiac hypertrophy. The blood Wassermann reaction is usually negative, syphilis being a rarity in these cases.

In the differential diagnosis, the authors consider coronary occlusion with cardiac infarction, angina pectoris, saccular aneurysm which has a relatively insidious onset, cerebral hemorrhage, spontaneous collapse of the lung, pulmonary embolism, a mediastinal new growth or abscess and, finally, acute abdominal conditions such as ruptured peptic ulcer, cholelithiasis or nephrolithiasis.

The authors have been able to collect 127 cases with clinical data from the English literature. In a summary of these cases they state that the age was given in ninety-five. The youngest patient was seventeen and the oldest seventy-six years. There were 69 males and 24 females listed. In 97 cases in which the race was given 80 were white and 17 were Negroes. A history of hypertension was given in 60 cases. Shock was present in 44 cases, while pain was noted in 80 patients. In 12 cases there was no acute onset. Associated symptoms included temporary loss of vision, fainting, numbness and paralysis, bloody sputum, dyspnea, choking, cyanosis, and nausea and vomiting. Fear of impending death was present in 6 cases. Roentgen examination was done in 22 cases and showed an increased aortic shadow in 16, cardiac hypertrophy in 9, pleural effusion in 8 and a shadow surrounding a vessel in one.

In conclusion, the authors state that roentgen examination is of value as confirmatory evidence and that the electrocardiogram may be of some help, particularly if tracings are made each day. An existing hypertension, with perhaps a sudden sharp increase in the arterial pressure, is the provoking cause of rupture in the majority of patients.—*S. G. Henderson.*

ABDOMEN

Fries, Joseph H., and Zizmor, Judah. Roentgen studies of children with alimentary disturbances due to food allergy. *Am. J. Dis. Child.*, Dec., 1937, *54*, 1239–1251.

There are comparatively few reports in the literature dealing with roentgenographic visu-

alization of the allergic gastrointestinal tract. All the previous studies, the authors found, were made on adults. Their present study deals with roentgenographic observations of the gastrointestinal tract in children after the deliberate oral administration of the allergic foods and in some instances after rectal administration. Patients were chosen who demonstrated repeatedly a definite gastrointestinal disturbance following the ingestion of a specific food. The study of each patient included taking of a detailed history, a physical examination, cutaneous tests, trial feedings and eliminations and later deliberate feeding of allergic foods. Comparative roentgen studies were made, first with an ordinary barium sulphate meal and at a later date with a barium meal containing the specific food to which a patient was sensitive. Roentgen studies consisted of fluoroscopic examinations and roentgenograms taken immediately after the barium meal and at three, six, twenty-four and forty-eight hours thereafter. Enough allergen was given to produce gastrointestinal disturbances, the amount having been previously determined by clinical trials. About one week was allowed to elapse between the control study and that made with the barium and allergen combined. Twelve patients were studied by oral and rectal administration of the allergens. Six were sensitive to egg, two to milk, one to nuts, one to oats, one to wheat and one to corn.

Peristaltic disturbances in various parts of the gastrointestinal tract were noted in these cases following the feeding of the allergic foods. These disturbances manifested themselves as gastric retention, increased or decreased motility of the stomach and intestines, and spasm and dilatation. They varied in type and intensity.

In making studies with persons who have pronounced gastrointestinal disturbances on ingestion of particular foods, the possibility of a constitutional reaction following oral and particularly rectal, administration of the offending foods must be considered. The authors hope that with improvement in technique, it may be possible to avoid such untoward reactions. Cutaneous reactions in the cases studied, produced by the scratch and intradermal methods, were slight in some patients, even though the allergy to the particular food had been proved clinically. In these patients small wheals with a surrounding erythema were obtained. The patients who manifested a severe gastrointestinal disturbance after ingesting specific foods apparently had more clearly positive skin reactions, such as a large wheal with pseudopod formation and a surrounding zone of erythema.—*R. S. Bromer.*

PRÉVÔT, R. Ergebnisse neuzeitlicher Röntgenuntersuchungen am operierten Magen. (Results of recent roentgen investigations on the operated stomach.) *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1937, *56*, 369–386; 499–520.

These studies are based on the methods of mucosal relief detail developed by H. H. Berg. The importance of the preparation of the patient through fasting and at least two cleansing water enemas is emphasized. A water barium mixture in proportions of 400:300 having a creamy consistency is recommended for the barium meal. An apparatus permitting rapid change from fluoroscopic work to the taking of the film is preferable. If barium enema studies are to be carried out, it is recommended that they be made before the barium meal. Before studying the stomach the chest is surveyed with particular attention to the movements of the diaphragm. As the patient drinks the meal, the retrocardiac region is examined with a small shutter opening. The meal should consist of two or at the most three small swallows of the mixture. Light palpation reveals the pliability of the stomach walls and character of the mucosal folds. The operative site is studied in full view and especially in profile by rotating the patient.

(*a*) *Sutures.* The author describes various types of sutures and shows by illustrations and diagrams how they appear in the barium study. The appearance produced by plications carried out following perforations is well demonstrated. The deformity is usually without significance in the stomach, but in the duodenum may be large enough to produce obstructive symptoms. The inverted edges may be so prominent as to suggest a neoplasm.

(*b*) *Local excision.* The removal of benign tumors and formerly of ulcers was carried out by means of wedge-shaped or elliptical incisions. The deformity produced by such a procedure is often difficult to recognize. When the operation has been on the lesser curvature of the stomach, an hour-glass deformity results which closely resembles that produced by the scar contraction of an ulcer.

(*c*) *Transverse resection.* The simple segmental and the step-shaped resections are described together with the resultant deformity as it appears in the barium-filled stomach. Again differentiation from the scarring produced by an ulcerating gastritis is difficult.

(*d*) *Gastroenterostomy.*

(1) Retrocolic. Diagrams showing the isoperistaltic and anisoperistaltic types are given. The author differs from the opinion of most surgeons and roentgenologists in considering the distinction of the two types an important one. He believes the anisoperistaltic type often, even though not always, produces the circus movement of the meal. So-called "spastic functional" phenomena usually have an organic basis, such as edema. The stomach folds converge upon the stoma in a star-like pattern and are not to be interpreted as the star-shaped scar about an ulcer crater. One observes the opening and closing of the stoma. The distal loop usually fills first because it lies isoperistaltically and later the proximal loop fills. If the pylorus is obstructed the proximal loop may not fill at all. If the stomach empties entirely through the pylorus, it may be difficult if not impossible to recognize a gastroenterostomy. Disturbances occur very much more often with the retrocolic than with the antecolic gastroenterostomy.

(2) Antecolic. Here the isoperistaltic position of the jejunal loop is not so important for an enteroenterostomy is usually performed below the gastroenterostomy. It is not always possible to demonstrate the enteroenterostomy with certainty. The mucosal folds lie transversely at the anastomosis and are broader than elsewhere in the small bowel. The anastomosis is often painful on pressure although no alteration in the mucosal pattern is demonstrable.

(3) Billroth I. In the roentgen picture one sees a small stomach which more closely resembles the normal stomach than that following any other operative procedure. The discrepancy between the size of the opening as it appears at operation and in the roentgenogram is to be explained by the loss of tonus under the narcosis incident to the operation and by the inflammatory swelling and erosion of the mucosa which occur subsequent to the operation. The most common complication of this operation is stenosis and much less commonly an ulcer recurrence.

(4) Billroth II. This operation becomes necessary if large portions of the duodenum or stomach must be excised and an end to end anastomosis is no longer possible. Only rarely is it possible to fill the duodenal stump completely with barium. In some types of operations there is a rhythmical opening and closing of the stoma while in others there is a continuous flow of material from the stomach.

(*e*) *Subtotal gastric resection.* Here one finds roentgenographically an end to side anastomosis of the esophagus and small bowel. By scarring, the small bowel anastomosis may be drawn through the esophageal hiatus into the chest. Early recurrences of the original lesions are often difficult to differentiate from scars. After such an operation the esophagus and the upper part of the small bowel often dilate.

(*f*) *Esophagogastrostomy.* This operation is carried out for organic stenosis as well as for cardiospasm and is accomplished through the transpleural route according to Sauerbruch or through the peritoneal route according to Heyrowsky. Often the operation brings no relief in cardiospasm. Fluroscopically one may observe the passage of the barium through the two openings into the stomach.

(*g*) *Inflammatory changes.* Only rarely is the delicate mucosal pattern of the normal stomach observed in one which has been operated upon. While prominent mucosal folds are no direct indication of inflammation, it is good evidence when found associated with stiffness of the walls, lack of pliability under palpation, and a bizarre pattern. These changes are particularly marked at the site of the anastomosis and in the distal jejunal loop. One may also observe evidence of increased mucus production and an accelerated passage of the barium in the affected areas. Gastroduodeno-jejunitis is a very common postoperative complication (Wanke 73 per cent) with or without ulcer and may or may not give ulcer symptoms.

(*h*) *Adhesions.* Adhesions may be demonstrated at the operative site following almost all operations, but their significance is much less than is generally assumed. The only important adhesions are those which lie across the bowel and produce stenosis causing acute or chronic intermittent ileus. With such symptoms, however, it is important to exclude the possibility of gallstone and renal stone colic.

(*i*) *Scar stenosis at the anastomosis.* This occurs frequently in wedge-shaped excisions and in transverse resections with end to end anas-

tomosis as in the Billroth 1 type of operation. Scar tissue is difficult to differentiate from inflammatory swelling and this can often only be accomplished after repeated examinations with the patient on medical therapy.

(*j*) *Recurrences in the mesocolon.* In the diagnosis of scar formation one must take into account the possibility of carcinoma metastases occurring in the mesentery and encircling the bowel or stomach to give a picture resembling that seen in scar formation.

(*k*) *Jejunal ulcer.* This common complication may be seen following all types of postoperative procedures, but in the author's experience is less frequent following the Billroth 1 operation. The cause is not to be laid to some technical failure as was formerly assumed but to the nature of the ulcer disease itself with the tendency to inflammation and ulceration of the mucosa. The ulcer most often occurs at the anastomosis, in the proximal or distal loops or occasionally at the site of the enteroenterostomy. The roentgen diagnosis depends on the demonstration of an ulcer crater. The author cites the case of one patient who experienced seven penetrating ulcerations with poor results under either medical or surgical treatment. The symptoms, tendency to perforation and hemorrhage, are the same in jejunal as in gastric or duodenal ulcers.

(*l*) *Gastrojejuno-colic fistula.* This most unfortunate complication results from a penetrating ulcer extending into the transverse colon which has become embedded in dense adhesions at the site of the anastomosis. The nutritional disturbance which this produces may threaten life. The investigation of such cases should be carried out first by means of the barium enema and later the barium meal. Such fistulas almost never heal spontaneously and are an indication for operation.

(*m*) *Niches and depressions.* These resemble ulcer craters, but show no mucosal folds and have a pliable wall. They are seen in the duodenal bulb as well as at the site of an anastomosis after the healing of an ulcer. They may be produced at the point of tension of a suture.

(*n*) *Motor disturbances.* These may occur as the result of scarring which has produced stenosis or angulations and the usual site is at the gastroenterostomy opening. The most serious of these disturbances is the circus movement of the stomach and duodenal contents which has been observed directly. Retroperistaltic motions are also seen in the stomach and duodenum which have not been operated upon. Backflow of the duodenal contents is seen in many inflammatory conditions, particularly gastroduodenitis. Such disturbances are not constant, but intermittent with symptom-free periods. The author believes that the condition cannot be regarded as a purely functional one but that anatomical considerations play an important rôle.

(*o*) *Pockets.* A circumscribed dilatation of the jejunum sometimes occurs beyond the anastomosis and is attributable to the atonic condition of this portion of the bowel as a result of the operation in contrast to the contractions which occur at the stoma. This is usually harmless, but occasionally the dilatation may be so great as to cause obstruction by pressure on neighboring loops. These pockets may greatly diminish in size during symptom-free periods.

(*p*) *Carcinoma at the gastroenterostomy ring.* The case is described of a man, aged fifty-seven, who had a gastroenterostomy for a duodenal ulcer in 1916. He was free of symptoms until the summer of 1935 when he suffered gastric pains, vomiting, and tarry stools. At operation a large tumor (carcinoma with mesenteric metastases) was found at the gastroenterostomy stoma. The roentgen findings and basis for the preoperative diagnosis are described and illustrated.—*W. A. Evans, Jr.*

CASE, JAMES T. Comparison of methods of roentgen examination of the colon. *J. Am. M. Ass.*, June 12, 1937, *108*, 2028–2034.

To emphasize the contrast presented by the elaborate roentgen study of the colon as practiced now, with indications for its use covering a very wide range of pathologic possibilities, the author was asked to offer a review of the evolution of the technique of roentgen examination of the colon, followed by an evaluation of the different methods. The colonic study with the opaque meal gives information more especially regarding function, whereas the contrast enema affords data relating to organic lesions.

The contrast enema had its inception early in the history of roentgenology through the work of Cannon and Williams, Hemmeter, Rieder, Pfahler, and others. Pfahler, Cole and other practiced air injections into the colon as early as 1907. Publications of Pfahler, of Cole

and of Haenisch in 1910 and 1911 definitely established the contrast enema as a dependable method of colonic diagnosis. Haenisch's "trochoscope," the forerunner of the horizontal fluoroscope, and Case's foot switch with room light control were of much help in facilitating roentgenoscopy. The author early began the practice of turning the patient into the left oblique position, and often to the right to better study the rectum and sigmoid. Straight lateral films of the rectosigmoid are sometimes helpful. Preparation of the colon by preliminary cleansing enema is essential.

The opaque enema should be the first roentgen procedure whenever the lesion is thought to be obstructive or potentially obstructive in nature. Fisher in 1923 popularized the idea of the double contrast enema. Based on the original work of Forssell various workers developed methods for showing the internal mucosal relief of the intestinal tract. Proper double contrast study for delineation of the mucosal pattern requires thorough preparatory cleansing of the colon. In marked atonicity of the colon, the use of a cold contrast enema enables the patient to make a better expulsion of opaque material preparatory to the insufflation. The possibility of rupture of a diverticulum or of passage of air through small openings in diverticula is considered. In cases in which insufficiency of the anal sphincter inhibits the use of either the barium enema or the injection of air, the oral use of umbrathor may be helpful.

The usual method of routine examination of the colon by contrast enema is described. The necessity of close fluoroscopic observation from the time the barium enters the anal canal is emphasized. Impatience and press of work are incompatible with successful fluororoentgenography of the colon. Overdistention must be avoided. Twenty-five years ago Holzknecht and Singer in Vienna showed that marked insufficiency of the ileocolic valve is one of the roentgenologic characteristics of the irritable colon. More satisfactory study of the right side of the colon is possible if the patient is allowed first to expel part of the contrast enema. If the patient will wait for ten or fifteen minutes before evacuating, and then avoid violent expulsive efforts, a better contrast enema will often result. Small boluses of gas in the third row of haustra may be mistaken for multiple polypi. Observation of the contracted colon following expulsion of the contrast enema in the case of small intraluminal tumors may reveal a localized fusiform enlargement of the bowel. For artificial demonstration of the internal relief of the bowel without insufflation, the bowel is thoroughly cleansed, followed by slow injection, without overdistention of the colloidal thorium or other opaque material. Umbrathor is very expensive. It contains an astringent agent which probably explains its usefulness, and if the ordinary contrast enema is rendered slightly astringent by the addition of 1 per cent tannic acid, it seems to answer the purpose equally well at a fraction of the cost. More important than the mucosal relief pattern is the constant finding of a circumscribed narrowing of the lumen or encroachment into the lumen, and a delineation of the exact contours of the afferent and efferent stretches of mucosa in the vicinity of the defect.—*S. G. Henderson.*

### GYNECOLOGY AND OBSTETRICS

MATHIEU, ALBERT. The diagnosis of tubal pregnancy. *J. Am. M. Ass.*, Jan. 30, 1937, *108*, 366–369.

This discussion is limited largely to the diagnosis of tubal pregnancy. The physician must remember that any vaginal bleeding in the child-bearing age following a missed period might possibly mean an ectopic pregnancy.

The best positive evidence by pelvic examination is obtained by palpating the cervix and uterine body. The cervix may be soft or patent, the body of the uterus is usually enlarged and movement of either cervix or fundus causes pain. Eight types of pain, which are connected with ectopic pregnancy, all explainable on a pathologic basis, are discussed. A negative Aschheim-Zondek or Friedman test merely means the absence of living chorionic tissue, and does not exclude ectopic pregnancy. When the fetus dies or when the pregnancy is disrupted, the decidual lining of the uterine cavity is cast off and bleeding occurs. When fluid is felt in the posterior cul-de-sac, needling is often of great value in diagnosis, but not conclusive. The sign described by Cullen is the presence of an area of ecchymosis in the tissues of the umbilicus. This sign is a rare finding. It indicates an actual hernia, plus some break in the integrity of the peritoneum at this site. Urobilinogen and icterus index tests are of value in determining the presence of a hematoma which might indicate ruptured ectopic pregnancy. The sedimentation rate is of value in a negative

way, differentiating ectopic pregnancy from salpingitis and pelvic abscess. Hysterosalpingography has been found of great value in diagnosis. In cases of tubal pregnancy aborting from the distal end of the tube, the injected oil enters all the crevices between the aborting pregnancy and the walls of the distal end of the tube in such a way that it literally drapes itself about the mass, and allows the oil-covered mass to be visualized roentgenologically. In tubal pregnancy in the midportion of the tube the injected oil passes to the site of the pregnancy and, because this site is apparently well walled off, ends abruptly and shows in a characteristic shadow.

Acute appendicitis, salpingitis, twisted ovarian cyst and rupture of a graafian follicle or corpus luteum with sufficient hemorrhage to cause symptoms must be differentiated from tubal pregnancy.—*S. G. Henderson.*

SKELETAL

Oppenheimer, Albert. A peculiar systemic disease of the spinal column (platyspondylia aortosclerotica). *J. Bone & Joint Surg.*, Oct., 1937, *19*, 1007–1017.

This paper deals with a peculiar disease of the vertebral column which Oppenheimer states has not been described in the literature and which seems to be uncommon. He has observed 6 cases in the course of five years. The characteristic finding is the coexistence of strongly marked calcification of the thoracic and abdominal portions of the aorta with a systemic spinal disease.

He describes the roentgenographic findings as follows:

1. Generalized demineralization of the whole spinal column, without similar decalcification of other parts of the skeleton.

2. Flattening of the bodies of a number of the vertebrae, with concavity of their upper and lower borders.

3. Marked widening of the intervertebral spaces, which appear rounded because of the concave borders above and below them.

4. Extensive calcification of the aorta, both in the thoracic and in the abdominal portions.

The intervertebral discs are not involved, at least not primarily, but they do expand and encroach upon the space originally occupied by the adjacent and softened bones. No signs of any hypertrophic reaction can be found, nor is there evidence of arthritis in the apophyseal articulations. On the other hand, slight calcifications in the longitudinal ligaments are to be seen occasionally.

Clinically, no evidence of parathyroid disturbance was found in any of the cases. While the calcification of the abdominal and thoracic aorta was extensive, peripheral and cerebral arteriosclerosis were not evident. Except for the gradual formation of a gibbosity, the disease does not cause marked subjective symptoms.—*R. S. Bromer.*

Heyman, Clarence H. Spinal-cord compression associated with scoliosis. *J. Bone & Joint Surg.*, Oct., 1937, *19*, 1081–1088.

Heyman collected 28 cases of cord compression complicating scoliosis, since 1913, and reports an additional case. The condition is rare. In a study of museum specimens showing markedly severe scoliosis, it has been the common observation that the size of the spinal canal is adequate for the spinal cord without bone encroachment upon it. The complication occurs in cases of long-standing scoliosis. Sixty per cent of the reported cases were of the congenital type and 40 per cent were due to infantile paralysis. The rapid growth changes during adolescence and the inability of the spinal cord to accommodate itself to these changes are the likely explanation of the compression, since practically all of the reported cases of paraplegia occurred during this active growth period. The paraplegia begins with no root symptoms and progresses rapidly.

Heyman's patient was a girl of ten years who showed on roentgenographic examination a congenital scoliosis of the upper dorsal region with wedge-shaped vertebrae and fused ribs. Three years after she was first observed the paraplegia developed. Laminectomy was performed and at the age of seventeen, two years after operation, she remains completely well.

While recovery, in some of the collected cases, followed conservative treatment, laminectomy has resulted in a higher percentage of cures. Heyman is not able to arrive at any conclusion on the question whether spinal fixation and fusion will prevent cord compression. —*R. S. Bromer.*

Mayer, Leo. The importance of early diagnosis in the treatment of slipping femoral epiphysis. *J. Bone & Joint Surg.*, Oct., 1937, *19*, 1046–1051.

Mayer emphasizes the fact that early diag-

nosis is the key to successful treatment of slipping of the upper femoral epiphysis. The diagnosis can be made with certainty from the history, the physical signs, and the characteristic roentgenographic picture.

In studying roentgenograms of the hips of normal children, Mayer draws attention to the bulging shadow, cast by the hemispherical head, at its junction with the upper margin of the neck. This lies just proximal to the oblique line, indicating a lighter shadow caused by the epiphyseal plate. The first sign of slipping is the disappearance of the slight bulge, and conversely, the appearance of a slight prominence of the upper margin of the neck. These roentgenographic changes are due to a combination of two motions which appear to occur synchronously, namely, a forward displacement of the neck (an anteversion which Milch has taken pains to emphasize) and a slight downward and backward displacement of the head. Because of this, the vertical diameter of the head becomes slightly diminished. In many cases, there can also be seen a broadening of the epiphyseal line, no doubt due to the changed projection caused by the slipping. In the lateral view of the head, the downward displacement of the capital epiphysis is usually well seen. The clinical signs are a slight limitation of internal rotation and of abduction

Mayer believes that treatment should be instituted at once and should be carried through until bony union has occurred between the head and the neck. This can be secured by either a Smith-Petersen nail or a bone graft, or bone screws, or impaction, or the drilling method.—*R. S. Bromer.*

Durham, Herbert A. Ischiopubic osteochondritis. *J. Bone & Joint Surg.*, Oct., 1937, *19*, 937–944.

Durham reports 5 cases of ischiopubic osteochondritis, the average age of the patients being seven and one-half years. This condition occurs only during the first decade of life, since the conjoined rami of the ischium and the pubis are completely ossified and fused by the tenth year. Little is known of the etiology. Probably the two factors which have been given the greatest amount of consideration as causative agents are trauma and infection, with the weight of the evidence in favor of the former.

The symptoms and findings on physical examination are quite typical. Pain referable to the hip or groin is essentially present. The child walks with a definite limp and protects the affected side, if the pain is not so acute as to prevent weightbearing altogether. Tenderness along the descending ramus of the pubis, with or without swelling, is characteristic and immediately suggests the diagnosis. Muscle spasm, particularly of the abductors, is constantly present in varying degrees. No swelling or tenderness is demonstrable in the hip joint. The temperature may be within normal limits or may be elevated. Moderate leukocytosis is usually present.

The roentgenogram is typical and establishes the diagnosis. Rarefaction, roughening and irregularity of the ischiopubic junction is shown. The reproductions of Harden's cases show these changes in excellent fashion.

The treatment consists of recumbency and traction to the affected hip.—*R. S. Bromer.*

Kennedy, Roger L. J. Hypertrophic pulmonary osteo-arthropathy in infants and in children. *Am. J. Dis. Child.*, Oct., 1937, *54*, 795–805.

Kennedy states that hypertrophic pulmonary osteo-arthropathy, or Marie-Bamberger's disease, in children has been reported infrequently. The clubbing of the fingers which occurs in this condition is a change usually confined to the soft tissue. There are cases, however, on record in children as well as in adults in which an irregular, burlike widening of the distal phalanges has been observed roentgenographically. In the rest of the skeleton, the changes consist of slowly progressing ossifying periostitis, beginning usually in the distal ends of the diaphyses of the bones of the forearms and the legs and later involving also the other bones of the limbs and even in some cases, nearly all the remaining bones of the skeleton. Later in the course of the disease, and coincident with the periosteal proliferation, there is also rarefying osteitis of the shafts, with fatty changes in the marrow. At first the new periosteal bone is clearly differentiated from the old, but later, two or three years afterward, the two become more or less fused, whereupon in most places they are indistinguishable. The joints may show swelling and erosion of the cartilage, and they are sometimes involved in a destructive process. The changes in the bones may undergo periods of regression and exacerbation according to fluctuations in the severity of the

primary disease and, as in one reported case, they may disappear entirely if the primary disease clears up completely.

In Kennedy's case multiple abscesses were found in the lungs at necropsy together with bronchopneumonia. On microscopic examination of the ribs and femurs the periosteum was greatly thickened, fibrosed and hyalinized. His case, he says, emphasizes the fact that the changes in the long bones can develop in a period of months rather than years and hence can occur in the first half year of life. This suggests that when clubbed fingers are found in infants and children, roentgenographic study of the skeleton should be carried out and may reveal the presence of pulmonary osteo-arthropathy.—*R. S. Bromer.*

McCUNE DONOVAN J., and BRUCH, HILDE. Osteodystrophia fibrosa. *Am. J. Dis. Child.*, Oct., 1937, *54*, 806–848.

This paper consists of an exhaustive case report and study of a patient who exhibited a syndrome of developmental anomalies which has few counterparts in the medical literature. The patient was a nine-year-old Jewish girl who exhibited true precocious puberty, asymmetrically distributed fibrocystic osteodystrophy of a progressively incapacitating nature, and unchanging pathologic pigmentation of the skin. These changes were present from the second year of life. In addition, the child showed evidence of increasing hyperthyroidism since she was four years old. The plasma phosphatase activity was increased; in other respects numerous chemical examinations of the blood gave normal results. Balance studies of the calcium and phosphorus metabolism yielded findings quantitatively similar to those obtained for healthy children. The patient showed no hypercalcuria. Biopsy of the bone did not provide clearcut information concerning either the precise classification or the etiology of the osseous dystrophy. Biopsy of the skin gave no important data. The evidence derived from measuring the concentration of parathyroid hormone in the blood and of gonadotropic and estrogenic substances in the urine was negative.

In a search of the literature, 8, possibly 9, females with an identical condition were found in case reports. Case reports of 5 males were found but while these patients showed fibrocystic osteodystrophy and pathologic pigmentation of the skin, they did not show precocious puberty.

The authors think that the occurrence of this triad of unusual phenomena in not only one but several persons suggests strongly the operation of a common causal factor. Critical scrutiny of the available evidence relating to the collected cases does not provide adequate grounds on which to base a satisfactory conjecture concerning the nature of the condition. While the fundamental pathologic condition may be an atypical variety of von Recklinghausen's neurofibromatosis, an unusual type of xanthomatosis or an unidentified disease of the hypothalamic region of the brain, they consider these and other surmises highly speculative.—*R. S. Bromer.*

CAFFEY, JOHN. Changes in the growing skeleton after the administration of bismuth. *Am. J. Dis. Child.*, Jan., 1937, *53*, 56–78.

Observations of Caffey revealed shadows in the skeletal roentgenograms of infants and children who had received bismuth in antisyphilitic treatment, similar to "lead lines." He describes four types of lesions to illustrate the changes which follow syphilitic therapy: (1) the lesion which occurs directly after a single course of treatment with bismuth; (2) that which occurs many weeks after a single course; (3) that which occurs after multiple courses during several years, and (4) that which occurs in the newly born whose mothers received treatment with bismuth during pregnancy.

In the first type a heavy transverse band of increased density is found at the end of the shaft. In the second, a transverse band is found deep in the shaft after a single course of treatment. In the third, multiple bismuth lines can be seen in the shafts after multiple courses of treatment. The lines lying deepest in the shafts, in his illustrative case, represented the courses of bismuth given earliest in the treatment and were narrower and less dense than the lines of more recent origin nearer the ends of the shafts. They faded out both laterally and medially, being completely absent near the cortex on both sides of the shaft. Another noteworthy feature of the two oldest lines was that they retained the same relationship to each other sixty months after the beginning of the treatment with bismuth as they had had twenty-six months after it, being separated from each other by exactly the same distance at both examinations. He regards this as an excellent illustration of the complete lack of longitudinal growth within the diaphysis of a long bone

after the epiphyseal cartilage has grown beyond any given level.

Roentgen examination of the bones of newly born infants whose syphilitic mothers had been treated with bismuth during pregnancy disclosed changes similar to those seen in the skeletons of infants and children who had been given bismuth post partum. Thus (1) after a single course late in pregnancy, bismuth lines occurred near the ends of the shafts; (2) after treatment relatively early in pregnancy, the lines were buried deep in the shafts and (3) multiple lines in the shafts occurred when the mothers received multiple courses of treatment.

Caffey produced changes in animals experimentally in the skeleton which were similar to those seen in human bones. These experimental lesions are described in detail in the article. Chemical analyses indicated that the actual bismuth content of the ends of the bones played a relatively minor rôle in the production of the roentgen shadow and that the calcium content of the compact cartilaginous matrix was from 9 to 17 times as important as bismuth in this respect. In similar lesions caused by lead, on the other hand, the extraneous metal is more significant. A comparison of the histologic changes following the administration of lead and bismuth disclosed some similarity but also distinct differences in the two lesions. The increase in cartilaginous matrix, the deficiency in endosteal bone and the reduction in the number of osteoblasts were all common to lesions produced by each metal. The presence of peritrabecular fringes of bony metaplasia has not been described in bones affected by lead; however, these were found by Caffey in the lesions produced by bismuth. Also, he did not find, after the administration of bismuth, the large number of giant cells reported by Park and his associates in lead poisoning. In one of his experimental animals, the administration of parathyroid extract prevented the development of peritrabecular bony metaplasia after the injection of a preparation of bismuth.—*R. S. Bromer.*

Harden, Albert S. Sickle cell anemia; changes in the vessels and the bones. *Am. J. Dis. Child.*, Nov., 1937, *54*, 1046–1051.

Harden states the purpose of this report is to record in the literature two further diagnostic features in the syndrome of sickle cell anemia. The first is the appearance of the skull which has been described in roentgenologic journals but which so far has had only verbal descriptions in clinical journals, with the exception of one paper by Moore. In the roentgenograms of Harden's cases the skull had the characteristic appearance, namely, the increase in thickness of the calvarium, the loss of continuity of the outer table of the skull, the replacement of the marrow cavity by radially placed bone formations simulating many individual hair shafts standing erect.

The second change was found in the eyegrounds which had an abnormal vascular appearance. The veins were greatly dilated and tortuous. The arteries were also tortuous but not to the extent shown in the veins. There was no sign of edema of the nerve head. The arteries and veins crossed at an oblique angle, without the compression which would occur in vessels with thickened walls. The caliber of the vessels was decreased evenly and not irregularly, as in vessels with diseased walls. Since no bony changes were shown in the base of the skull, the foramina were thought to be unaffected. It was therefore considered that the vessels were congenitally abnormal. The superficial temporal vessels were abnormal also, being extremely tortuous and thickened.

The long bones on roentgen examination showed the same changes which have been previously reported, moderate thinning of the cortex, with diffuse coarse irregular trabeculation of the medullary cavity, most marked near the ends of the bones.—*R. S. Bromer.*

### BLOOD AND LYMPH SYSTEM

Sgalitzer, M. Unterscheidung funktioneller und organischer Erkrankungen der Extremitätenarterien durch die Röntgenuntersuchung. "Das Doppelinjektionsverfahren." (Differentiation of functional and organic disease of the arteries by roentgen studies (the double injection technique).) *Fortschr. a. d. Geb. d. Röntgenstrahlen*, Sept., 1937, *56*, 387–404.

The ordinary roentgen study may show extensive calcium deposits in the arteries when no symptoms are present, and, on the other hand, may show very little or no calcification in cases with extensive arteriosclerosis and incapacitating symptoms. The injection of constrast media has been a great step in the study of arterial disease, and the author records his seven years' experience. His method consists in the rapid

injection of 20 cc. of a 40 per cent solution of uroselectan or similar medium into the exposed artery (in Scarpa's triangle in the thigh) which has been compressed proximally. The exposure is made during the injection of the last 3 cc. In order to demonstrate some of the smaller branches, it may be necessary to give a second injection with a compression band about the main branch.

Early arteriosclerosis is shown by the increase in the size of the lumen, by a slight bowing and by slight irregularities in the contour of the artery. In advanced cases the lumen becomes narrowed and occasionally completely occluded. In endarteritis obliterans there is by contrast primarily a narrowing of the lumen and there is no tendency to any tortuosity in the course of the artery. The defects in the lumen are not so angular, irregular and rough as in arteriosclerosis. Thrombo-angiitis or Burger's disease is similar to endarteritis obliterans, but the lumen is not narrowed except very suddenly at the site of the thrombus. This is distinguished from a simple embolic occlusion by the tortuosity of the finer branches pointing to the chronic nature of the former condition.

These organic disorders are to be distinguished from spastic conditions characterized by a gradual concentric narrowing of the arterial branches. Sometimes differentiation from endarteritis obliterans is difficult. The author believes many organic arterial diseases begin with clinical signs of spasm and that spastic and organic conditions may exist together. About a third of the advanced cases experienced definite relief following the diagnostic injection. This was attributed to the organic iodide, and the relief obtained was often lasting. The effect of the solution in causing vascular dilatation could also be observed in animals. If a second injection is made five to ten minutes following the first, the relief of spastic conditions in the arteries may be clearly demonstrated. This constitutes the "double injection technique." Three such cases are described with convincing illustrations.—*W. A. Evans, Jr.*

## ROENTGEN AND RADIUM THERAPY

WILE, UDO J., and HAND, EUGENE A. Cancer of the lip. *J. Am. M. Ass.*, Jan. 30, 1937, *108*, 374–382.

Over the ten-year period ending Jan. 1, 1935, 425 cases of carcinoma of the lip were seen at the University Clinic (University of Michigan Medical School). These cases were treated by local destruction, surgery and radiation therapy, and have been followed from one to ten years. Most cases of carcinoma of the lip fall into two clinical types: the papillary superficial elevated type and the ulcerative infiltrative type. Of the 425 cases, 96.4 per cent occurred in males and 3.6 per cent in females. As to location, 93.3 per cent appeared on the lower lip, 4.7 per cent on the upper lip and 2 per cent at the angles. The average incidence was 65.2 years. In a study of the final results, it was found that the younger groups fared much better than older groups. Syphilis apparently was of no great importance as an etiologic factor in the series. The greater prevalence of smoking, particularly pipe smoking, in the male may account in part for the great preponderance of cases occurring in males.

The 425 cases were divided into three groups. The early group included all those from the smallest to those the size of a nickel (21 mm.), numbering 216 cases. The moderately advanced group included those from the size of a nickel almost to that of a half dollar (30 mm.) in which the lesion was not fixed to the underlying structures of the lip or jaw, including 150 cases. The far advanced group was composed of 59 cases, many of which were inoperable and unsuitable for any form of therapy. Only 386 of the 425 cases received treatment in some form, 286 of these having received no previous treatment.

From a comparison of those cases treated by surgical excision alone and those in which some form of radiation therapy was given later following the surgical excision, the authors reach the conclusion that this subsequent radiation therapy is unnecessary. Palpable lymph nodes in cancer of the lip should be dissected in all operable cases. In cancer of the lip with non-palpable lymph nodes, metastases had apparently not occurred in early cases and were seen but rarely in the moderately advanced cases in this series. Therefore the surgical excision of non-palpable lymph nodes is not advocated. High voltage roentgen therapy to the glands is considered by the authors to be useless as a prophylaxis against metastasis. The results obtained with local destruction compare very favorably with the results with radium alone or with surgery alone, and much better

than with roentgen therapy alone. Methods employed in actual destruction of the local lesion are: curet and wide cauterization with the actual cautery, curet and chemical cautery with a strong acid, electrodesiccation, and, lastly, adequate removal with the electric cutting current following which cauterization of the bleeding exposed surface is done. Radium therapy is considered an excellent method of treating cancer of the lip, but in untrained hands recurrences of a particularly intractable type are common. The results with surgery plus dissection of the regional lymph nodes and local destruction as carried out by the authors were much better than those with irradiation only in this series. With roentgen therapy, under all but the best trained workers, recurrence of a particularly dangerous type is a not infrequent occurrence, and it is considered of little if any use as a prophylaxis against metastasis.

Grouping the previously untreated and recurrent cases, the authors find a 35.7 per cent five-year cure in cases presenting positive lymph nodes on dissection of the regional lymph nodes. All the five-year cures occurred in the previously untreated group, and in these the metastases were microscopic at the time of operation.

Numerous cases begin as basal cell carcinomas of the skin of the lip and invade the mucous membrane secondarily. In almost every case in which this involvement of the mucous membrane takes place, the carcinoma cell type changes to squamous cell type. The prognosis in basal cell carcinoma of the lip is extremely good. Metastases are almost unknown. A relative cure of 92.1 per cent, of which 20, or 52.6 per cent, were five-year cures, was obtained in the group of 38 cases classed as cell Type 1 (Broders). The results in Types 2 and 3 were progressively worse. Of the 9 Type 4 cases, death due to cancer of the lip occurred in 8, and the final case was recurrent with local extension to the mandible.

The cell type in cancer of the lip is apparently of prognostic value and should be used for this purpose and also may serve as a guide to the best mode of treatment.—*S. G. Henderson.*

Brindley, G. V. Carcinoma of the rectum. *J. Am. M. Ass.*, Jan. 2, 1937, *108*, 37–43.

Practically all patients with carcinoma of the rectum can be cured when adequate surgery is instituted early. Rectal cancers can be diagnosed easily and with certainty while the lesion is early and curable.

The author's paper is based upon a study of the records at the Scott and White Clinic of 167 patients having cancer of the rectum. He finds that the extent of the neoplasm is the most important modifying factor. Carcinoma begins in the mucous membrane from the crypts or glands of Lieberkühn. Its first method of spread is by continuity of tissue. The next is by metastasis through the lymphatics and occasionally by way of the blood stream. The more deeply the lesion has penetrated into the intestinal wall, the greater the probability of metastasis.

The symptoms and signs of early disease are: Blood in the stool; mild rectal discomfort; change in bowel habit. Practically all rectal cancers can be diagnosed by a careful digital and proctoscopic examination. The size of the lesion is a poor index of its curability. The papilliferous, fungating lesion grows chiefly into the intestinal lumen and metastasizes slowly. The ulcerating cancer of the adenoid or colloid variety which has penetrated deeply into the rectal wall, even though small, is frequently highly malignant, may metastasize early and often tends to recur after wide removal.

The pathology of rectal neoplasms is an important factor influencing the prognosis. A negative report does not exclude carcinoma: Specimens from 124 of the 167 patients showed: 26 papillary; 4 colloid; 91 adenocarcinoma (simplex); and 3 squamous cell epitheliomas. A definite majority of rectal carcinomas have a low degree of activity of the malignant cell. The author's findings indicate that rectal carcinoma is slow to metastasize to lymph glands and in the majority of cases remains local until late.

Factors affecting the type of treatment and the prognosis: *The degree of malignancy.* All definitely extirpable carcinomas of the rectum should be removed surgically. New growths of borderline operability and of a high degree of malignancy, and many extensive anal epitheliomas should be treated by radium and roentgen rays. Four factors related to pathology which materially affect the prognosis are,—the different clinical varieties of cancer, the degree of activity in the carcinoma cell, the depth of penetration of the intestinal wall by new growth and the presence or absence of glandular involvement.

*The mobility of the growth.*

*The sex of the patient.* The incidence is higher in the male, and surgical extirpation of the rectum carries a higher mortality for the male.

*The age of the patient.* Practically two-thirds of the patients under forty had highly malignant tumors.

*The physical condition of the patient.*

*The mental condition of the patient.* Radiation therapy offers the most to those patients who are not willing to have a colostomy, and to those who assume their condition to be hopeless.

*The location of the lesion.* The first symptoms of a rectosigmoidal cancer are frequently those indicative of a partial obstruction. Neoplasms of the rectal ampulla are usually cellular, fungoid growths, prone to early ulceration and bleeding, and blood and mucus are the usual first signs. Cancers of the anus, usually epitheliomas, early become fissured, ulcerated and infected, and in consequence discomfort and pain are experienced early.

*Improper first treatment*, many being treated at first for hemorrhoids or for colitis.

*The attitude of the physician*, some assuming that treatment of any kind is useless.

*The type and thoroughness of the operation performed.* Rectal neoplasms should not and cannot all be operated on by the same surgical plan.

Brindley believes that radiation therapy should be reserved for those who cannot, because of physical condition or degree of malignancy, or who will not have an operation, and as an adjunct to surgery. Practically all patients treated surgically were given either pre- or postoperative irradiation, or both. Brindley concludes that surgical removal of a malignant rectum is a relatively safe procedure, and that wide, hot-knife excision of early lesions gives a high percentage of permanent cures.—*S. G. Henderson.*

BERCK, MAURICE, and HARRIS, WILLIAM. Roentgen therapy for bronchiectasis. *J. Am. M. Ass.*, Feb. 13, 1937, *108*, 517–522.

The authors report their experience in 30 cases of chronic bronchiectasis in which roentgen therapy was employed. Bronchiectasis, as it is now known, cannot be accurately or completely diagnosed without the use of bronchography and bronchoscopy. The use of roentgen therapy in chronic inflammatory processes has a scientific basis of considerable clinical and experimental evidence. Roentgen rays act initially and mainly on the leukocytic (particularly lymphocytic) infiltration, causing destruction with ensuing phagocytosis and connective tissue proliferation. Exposure of the salivary glands to roentgen rays brings about a diminution verging on abolition of secretion. If a comparable reaction could be induced in the bronchial mucosa of bronchiectatic areas a comparable diminution of the secretion, and hence expectoration, might be expected. It is perhaps more logical to assume that the results in chronic bronchiectasis are due to the action of the rays on chronic inflammatory processes.

The origin of bronchiectasis is based essentially on primary morphologic alterations of the bronchial wall. Pathologic examination of the bronchial tree reveals it to be the site of a chronic and subchronic bronchial and peribronchial inflammation. The mucosa is either hypertrophic or atrophic. The cellular infiltration involves the submucosa as well as the deeper layers of the wall, is very dense and extends through the bronchial wall into the immediate peribronchial area. It is predominantly lymphocytic.

All the patients in this series were rigorously investigated and the diagnosis of chronic bronchiectasis was clearly established. It is of great importance to point out that chronic bronchiectasis is a diagnosis of exclusion. It is necessary to ascertain the presence or absence of various local features such as pulmonary tuberculosis, pulmonary abscess, bronchial foreign body, bronchial adenoma and bronchial carcinoma. The important therapeutic consideration is not the bronchial dilatation, but whether it is "wet" or "dry." The authors' use of roentgen therapy is to render a "wet" bronchiectasis "dry."

Active pneumonitis was considered a contraindication to the therapy. Roentgen therapy was instituted in three types of chronic secreting bronchiectasis: (1) Bronchiectasis secondary to chronic putrid lung abscess and residual symptomatically after pneumonotomy for the chronic abscess. (2) Patients with an involvement of one or two lobes, daily expectoration of 1 to 5 ounces of non-odorous sputum and rarely hemoptysis and pneumonitis. (3) Chronically ill patients with multilobar bronchiectasis, large quantities of foul sputum, frequent hemoptyses and attacks of pneumonitis.

Roentgen therapy was given in large dosage to these patients over a period of approximately three months, using three to seven fields in order to cross-fire the diseased lung. Average total dose was approximately 1,200 r to each area. Factors used in treatment were 180 to 200 kv., focal skin distance 50 cm., 4 ma., filter of 0.5 mm. copper plus 1 mm. aluminum, each field 10 by 15 cm.; 75 r, measured in air, to two or three fields were given at each treatment, the patients being treated two or three times a week. At least four months must be allowed to elapse after a course of therapy to secure the full measure of improvement.

During the course of treatment the patient's symptoms are exacerbated. Fever, cough, expectoration, episodes of pneumonitis and hemoptysis may be seen to an even greater extent than before treatment. After approximately three-fourths of the treatment has been finished noticeable improvement begins to take place. This is gradual and progressive. Improvement, while moderate in some instances, has been so striking and remarkable in others as to render patients practically cough and sputum free. The only criterion of improvement that the authors have employed is decrease in expectoration. Those patients who have responded to roentgen therapy have sustained their improvement during their entire follow-up examination to date, in some cases consisting of a period of over two years.

In some of the cases that have been treated successfully, post-therapy bronchography has shown alterations in the picture of the dilated bronchial tree. The bronchi appear narrowed and strictured throughout after treatment. In other cases, post-therapy bronchography, as yet, has shown no alterations in caliber of the dilated (now "dry") bronchi. Roentgenograms of the chest other than the aforementioned bronchographic changes have shown no alterations after roentgen therapy.—*S. G. Henderson.*

## MISCELLANEOUS

Failla, G., Twombly, G., and Marinelli, L. A method for decreasing the ionization in the skin applicable to supervoltage x-ray therapy. *Radiology*, June, 1937, *28*, 693–703.

The biological and therapeutic effects brought about by roentgen rays and gamma rays from radium are the result of ionization taking place in the tissue of the test object or patient. In the treatment of patients, part of this ionization is desirable and part is harmful, i.e., the ionization occurring in the tissues destroys the cells of the tumor and tends to bring about the results sought after, whereas that occurring in the skin or the normal tissue between the skin and tumor results in unfavorable reaction such as erythema, epithelitis, ulceration, etc. Thus the tolerance of the skin determines the tumor dosage. Part of the ionization effect in the skin is brought about by secondary electrons produced in the air and any other intervening matter between the radiant source and the skin. Due to the short distance traveled by a secondary electron generated from 200 kv. (peak), it is evident that it is not worth while to try to eliminate these electrons. However, with voltage of 1,000 kv. (peak), these electrons are a large factor in the amount of skin reaction produced and hence any method which would eliminate a large part of these electrons produced in the air, would definitely increase the amount of radiation available to the tumor.

The authors found that secondary electrons may be removed from a beam of radiation by means of a magnetic field suitably applied. They may also be removed to a considerable extent by proper canalization of a narrow beam, on account of the fact that they do not travel in straight lines. When a beam of radiation stripped of secondary electrons traverses a tissue, it gradually acquires secondary electrons due to the interaction of radiation and matter, and beyond a certain depth it contains the appropriate quota of electrons consistent with the physical characteristics of the radiation and medium. Accordingly, it is only within a certain layer of tissue on the incidence side that a subnormal degree of ionization may be expected. The thickness of this tissue layer depends on the quality of the radiation which determines the penetration range of the secondary electrons. In the case of ordinary roentgen rays the range in tissue of the secondary electrons is very short and the tissue layer of subnormal ionization is very thin. In the case of gamma rays it is of the order of a few millimeters.

The skin damage of the degree tolerated in present-day radiation therapy is probably limited to the epidermis, inasmuch as there is eventually almost complete recovery. The thickness of the human epidermis varies from point to point but in general, it is well within 2 mm. Accordingly, by removing the secondary

electrons from a beam of gamma rays before it reaches the skin, one may expect to reduce skin damage considerably.

Physical experiments described in the body of the paper show that in the case of gamma rays the tissue layer of subnormal ionization is about 4 mm.

Biologic experiments with *Drosophila* eggs as test objects confirm this result, and demonstrate that the biologic effectiveness of gamma rays is markedly reduced by the removal of secondary electrons.

It has been impossible to test by actual experiment the decrease in skin damage resulting from the removal of the electrons from a gamma-ray beam, due to the fact that the amount of radium required for this purpose (about 20 grams) was not available.

The authors suggest that practical application of the findings reported be made to supervoltage roentgen therapy at voltages in the neighborhood of one million.—*J. H. Harris.*

Packard, Charles. The biological measurement of depth doses. *Radiology*, July, 1937, *29*, 12–21.

Because of the differences in the results of measuring depth doses by means of ionization chambers, the author has experimented extensively with a biological method. He proves that the biological method using *Drosophila* eggs, is accurate within $\pm 3$ per cent. The procedure of making surface and depth dose determinations is described. He found that under large portals (225 and 400 sq. cm.) the intensity of radiation in the first 5 cm. below the surface of a water phantom is found to be higher than heretofore reported. This is due to the large amount of scattered radiation which has been measured. At the surface and at depths greater than 5 cm. the intensities are not significantly different from those given by Grebe and Nitzge. Under smaller portals (50 and 100 sq. cm.) no unusually high depth dose values were found. The intensity of radiation at points outside the central beam was determined.—*J. H. Harris.*

Kerr, H. Dabney, and Evans, Titus C. A biologic test of the inverse square law as applied to roentgen radiation. *Radiology*, July, 1937, *29*, 45–51.

In a series of experiments upon the effect of irradiating grasshopper eggs at different distances it was found that in some experiments the effect appeared to fall off according to the inverse square law. In others the curve of the biological effect was modified by:

(1) The effectiveness of the dosage at the shortest distance.

(2) Developmental stage of biologic test material and the way in which the material responds to changes in amount of radiation.

(3) Intensity *per se*.

(4) Low intensities where time allows some recovery or enough development to make the organism resistant.—*J. H. Harris.*

Robertson, Elizabeth C. Intestinal stasis due to low mineral intake. *Am. J. Dis. Child.*, Feb., 1937, *53*, 500-509.

About two years ago in the course of some other experiments, the author noted that rats fed a diet low in minerals showed intestinal stasis. This was shown in further studies to be accompanied by much delayed excretion of carmine and barium and by dilatation and overloading of the large intestine. When calcium and potassium salts were added to diets deficient in minerals, practically no stasis occurred. The contents of the large intestines were definitely more acid in rats showing stasis than in the controls.

Nineteen children were fed diets low in calcium and potassium and, of these, 14 showed constipation. When given a barium meal, 33 per cent of 18 children fed diets low in calcium and potassium retained the barium in the appendix for abnormally long periods (from four to twenty-one days). The same children, when fed normal diets, did not show barium in the appendix for more than one day.—*R. S. Bromer.*